COMMUNICATION OF SOIL SURVEY AND RELATED SOIL MANAGEMENT INFORMATION

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This is to certify that the

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ABSTRACT

COMMUNICATION OF SOIL SURVEY AND RELATED SOIL MANAGEMENT INFORMATION

by Roger Pennock Jr.

This investigation studied the effectiveness of communication by several sources of soil survey and related soil management information to several groups of potential users. A circular "Know Your Soils," the Sanilac Soil Survey Report, and a Teaching Program on soil properties and soil management groups were compared as sources of soil management information on the soils of lower Michigan.

The circular, prepared in 1962, was evaluated first by distributing it for use by a group of agricultural extension agents. The agents were subsequently interviewed to obtain their evaluations of the circular. A training and evaluation seminar requested by the agents was subsequently held. This gave further opportunity to evaluate the usefulness of the circular, the Sanilac,and Lenawee County Soil Survey Reports in communicating soils and soil management information and to determine changes needed to improve their effectivenesses.

The circular was revised as the 1964 "Know Your Soils." Improvements in it included: (1) reorganization into independent sections, (2) revision for increased accuracy and clarity, and (3) inclusion of useful additional information. The revised edition was extensively tested with a wide range of potential user groups. These included vocational agriculture students, farmers, college students, vocational agriculture teachers, professional soil conservation personnel, and university soil science staff. It was compared with the Sanilac County

Soil Survey Report and a Teaching Program on soil management groups as sources of soil management group information. The effectiveness of "Know Your Soils" and the Sanilac Report were measured first without and then with a soil management problem.

Increased learning was measured by a pretest, treatment (with the respective information source), and a posttest procedure. Selected groups were subsequently given a soil management problem then post-posttested to determine its added affect.

The effectiveness of communication by "Know Your Soils" and other sources can be summarized by examining the changes in test scores for low capability groups, medium capability groups, and high capability groups as indicated by their pretest scores.

Low capability groups received little benefit from their exposure to "Know Your Soils" as indicated by their small change in scores. This may have been due to a lack of motivation, or insufficient background knowledge to give them a base from which to learn new information.

"Know Your Soils" was much more effective in communicating soil management information to the medium capability groups. This was illustrated by significant increases on the overall test for all such groups. Added instruction given as lecture material resulted in a more notable increase on items covered in the lecture and "Know Your Soils." Working of a problem gave further significant increases in student scores.

The effect of treatments on high capability groups demonstrated their ability to make significant increases in scores despite relatively high initial scores.

Students using the Teaching Program had average total test score increases greater than those using "Know Your Soils" or the Sanilac Report. This was unexpected as the Teaching Program only provided information for answering 12 of the 40 test items. However, appreciable increases in scores occurred only on those 12 items. These results indicate that greater total learning may occur when a limited amount of information is thoroughly covered than when a broader range of information is given less thorough coverage. A marked decrease in score occurred on one item due to confusion of plow layer textures with profile textures emphasized in the soil management groups.

The kinds of information most effectively communicated by the various sources were also studied.

COMMUNICATION OF SOIL SURVEY AND RELATED SOIL MANAGEMENT INFORMATION

by

Roger Pennock Jr.

A THESIS

Submitted to
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DOCTOR OF PHILOSOPHY

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To my wife
and children

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INTRODUCTION

This study was conducted to determine how to increase the effective communication of soil survey and soil management information to individuals for whom it would be useful. The study consisted of five major phases: (1) developing a test procedure for evaluating comprehension and learning of essential soil management information to be communicated, (2) an evaluation of the limitations and contributions of a soil management circular for communication of soil survey and soil management information, (3) steps taken to revise the circular to improve its accuracy, useability, and effectiveness, (4) an evaluation of the revised circular through testing with various groups, and (5) comparison of other sources of similar information to the revised circular.

LITERATURE REVIEW

Origin, Purpose and Kind of Soil Surveys

Kellogg (1966) states that the soil survey of the United States originated in 1899. The purpose of the soil survey during its first 25 years of existence was to supply information and maps useful for rural land use involving the growing of plants, grasses, and trees. During this period, much was learned about the soils of the United States and methods were developed for their satisfactory study. During the late 1920's Soil Science made great strides in soil mapping and in the understanding of soil properties. Air photos became available for base maps on which to do soil mapping, and increases in knowledge about basic properties such as clay minerals and soil chemistry advanced rapidly. Increased knowledge about soils including engineering information made possible increased usefulness in soil interpretations and therefore broadened the number and scope of users that found this information useful. The increase in knowledge about soils made possible a much broader application of soil interpretations, and soil surveys were put to use in highway construction, location of airfields, and other engineering applications that had previously been impossible. In recent years the usefulness of soil surveys and soil maps has been expanded to include use by people in planning housing foundations, septic tank disposal systems, and other features that are important in community planning or urban development.

Smith and Aandahl (1966) describe soil maps as a basic tool for the selection of soil management systems. They make the important point that if a person can see the effect of a given practice on a field in which the soil is known, they can then predict the effect of that practice on other fields where the same kind of soil is found. Soils are named and classified, just as animals and plants are, by their distinctive characteristics. These identifying characteristics for soils include kinds and numbers of horizons. Soils having the same narrow range in all properties will be given the same name and will occur on soil maps as areas identified by one or more such soil names. A soils map includes a base map often consisting of an aerial photograph on which the soil areas have been outlined and identified by symbols. A soil survey report contains descriptions of the soils and information on their suggested uses or management in addition to a soils map of the area covered by the report. The main purpose of soil maps is to show where different kinds of soils occur and thus make it possible to apply management that has proven successful through experience or experiments on similar soils elsewhere.

Since the initiation of soil surveys there have been great changes in both soil maps and the published material on soil management. These changes have resulted from an increase in knowledge about soils and their uses, improved mapping techniques and materials, and finally a large increase, particularly recently, of different kinds of uses to which soil surveys are being put. The Soil Survey of Saginaw County, Michigan (Moon, 1938) is an example of the type of survey published in the 1930's. It contains a colored map showing soils on a planimetric base at a 1 inch per mile scale. All soils of the county were shown on a single map sheet.

In 1960 the Soil Survey of Montcalm County, Michigan

(Schneider, 1960) was published at a scale of 3.17 inch per mile. This is a larger scale than had been used previously in Michigan in soil survey reports, but the soil map was still in color and on a planimetric base as previously. In the late 1950's soil survey reports started to use soil maps made on air photo bases and these have been used as a standard type of soil map since that time. An example is the Soil Survey of Lenawee County, Michigan (Striker, 1961). The maps in these reports are usually published at a scale of 3.17 inches per mile. Reports of this type also included a general soil association map printed in color, on a planimetric base, for the entire county, as compared to the air photo sheets which only cover 12 sections per sheet. An exception to the 3.17 inch per mile scale is the Soil Survey of Sanilac County, Michigan (Schneider, 1961) in which the maps were published at a 4 inch per mile scale as an experiment to determine if the larger scale would be more useful for present day soil survey uses.

In recent years with the rapid expansion of urban and suburban development there has developed an intense need for soil survey information to aid in the intelligent planning of these areas. These urgent needs have been met with the publication of soil maps and accompanying information that gives interpretations on engineering and other properties of the soil that are useful for the purpose to which these maps are to be put. Examples of this type of report are the Ela Township Soils of Lake County, Illinois (Newbury, 1961) and the Munster Soil Survey Report (Wenner, et al, 1964) of Indiana.

Uses of Soil Surveys

Bender (1961) discussing the suitability of soils for septic tank filter fields points out that the soil's absorptive capacity is extremely important. The soil must be able to both absorb effluent and to filter it sufficiently to prevent contamination of ground water. Soils that are extremely fine textured or resistant to absorption, or soils that are extremely coarse textured and permit movement of water through them too rapidly are unsatisfactory for septic systems. Soil maps are useful in determining the suitability of areas for septic tank systems as they give information on factors such as: ground water levels, depth to bedrock, amount of sand or gravel present, or the presence of restricting layers that prevent infiltration of effluent materials.

Morris (1966) points out the increased use of soils information in urban planning and its usefulness for this purpose. Soils maps were useful in demonstrating that small lots should be avoided in areas where septic systems had failed as a result of insufficient area of soils with good permeability. He also stated that soils information was useful in determining areas not suitable for building due to lack of stable foundation support material. County officials also found soils maps useful in working with developers of large subdivisions as these maps gave the officials and developers an opportunity to lay out a plan of development that was more satisfactory to both the developer and the county personnel in the long-run.

Bauer (1966) discussed the high value of soil surveys in regional planning. Regional planning necessitates determining the best use of land for various purposes. These purposes include:

(1) potential agricultural uses, including soil capabilities for crops and woodland, (2) wildlife habitats, (3) non-farm uses for lawns, golf courses, playgrounds, (4) soil water relations such as stream flooding, ponding or concentrated run-off areas, and (5) engineering uses, which are affected by soil depth, plasticity, maximum density, optimum moisture, pH, and other soil factors.

Thornburn (1966) gives the potential uses and limitations of agricultural soil surveys for highway construction. He stresses that in the initial planning of highway routes the general soils map or soil association map is more useful than the detailed soils map as it gives an overall picture of the kinds of material over which the right of way must pass. He also stresses that factors such as: kinds of parent material, depth to bedrock, and soil texture have an influence on the location of highways and obtaining of materials for subgrade fill. Detailed agricultural soil surveys have been useful in the design of low cost pavements on secondary roads. This is particularly true where the highway department has engineering specifications on the materials of the soil series over which the road will be constructed (Michigan State Highway Department, 1960). This information is used in the design of sufficient paving thickness needed to meet different subgrade conditions.

Van Eck, and Whiteside (1958) state that the use of soil maps should make it possible to indicate suitable locations for eatablishment of red pine plantations and predict the probable growth of these plantations if well managed. This is possible due to the observed relationships between the properties of many soils differing in natural drainage in the nature of their primary materials, and in the degree of development of the podzol B horizons if no textural B is present. Because of the known interrelationships among these soils it is possible to estimate the red pine cite index on soils similar or related to those which they had investigated.

Priest, Whiteside, and Heneberry (1963) used soil maps and the soils classified into soil management groups to evaluate farmlands and their utilization. Soil management groups include soil series, grouped together on the basis of similar profile textures and similar natural drainage classes. The soils contained in these groups need approximately the same management practices and should give similar yields of crops when managed similarly. They should have approximately equal values, based on income producing capacity, if other factors are equal. It was found that estimating farm value on the basis of soil management groups and their current uses agreed reasonable well with the farm values determined by two other methods.

Despite the many new uses to which soil surveys are being put, agriculture is still the largest user of soil survey information, except in areas where urbanization has largely replaced agriculture. Some of the agricultural uses of published soil surveys are (Southern Regional Soil Survey Work Planning Conference, 1962): (1) to enable agricultural experiment stations to relate their basic research findings on representative soils to the soils used for agricultural production on farms, (2) to aid vocational agriculture teachers, county agricultural agents, soil conservationists and others in the development and execution of their programs of work, (3) to aid in the selection of sites for test demonstration farms or experimental farms, (4) to aid agricultural engineers in planning irrigation, drainage, and pond or dam construction, and (5) to aid in forest management.

Soil maps are useful for identifying and locating major soil differences that should be taken into account during soil sampling for soil testing. Longnecker, (1961) notes that soils having large differences in texture or organic matter content, such as clay, sandy loam, or muck, should be sampled separately for soil testing. Separate samples should also be taken from soils that differ in natural drainage, or have major slope differences. The bulletin, Fertilizer Recommendations for Michigan Soils, (Soil Science and Horticulture Departments, Michigan State University, 1963) makes possible extensive use of soil survey information by basing fertilizer recommendations on soil management groups in addition to soil test results and the kind of crop to be grown.

As the knowledge about soils and the number of uses of soils information increases there is an increase in volume of information included in soil survey reports. It thus becomes more difficult, more time consuming, and probably less likely that the farm owner will put this information to use. Means for more effectively communicating this valuable information to the various users have therefore been sought. The report "Get the Most from Your Farmland" (Porter, et al., 1955), a soil survey summary for Odessa Township was an experimental attempt to simplify soil maps and soil survey information to make it more easily and readily used by farmers. It was "An attempt to abbreviate, summarize, and present the basic and essential information in a typical soil survey so that it can be applied to everyday use on your farm." The maps were direct reproductions of field mapping sheets with soil management group symbols added to each of the mapping units. The soil management information was simplified for ease of use by applying it directly to the soil management groups rather than to each of the specific soil mapping units. Research was conducted to determine the success of this type of publication in communicating soil survey information to farmer users. Results of this research are discussed later in this literature review.

Drawing on the experience gained from the writing of "Get the Most From Your Farmland" and its trial in Odessa Township, a subsequent circular "Know Your Soils and How to Use Them" (1962, Appendix F) was written. This circular dealt entirely with soil properties and soil management information. It contained no soil maps for a specific area. It was written to utilize available soil maps and the available soil management information with the soil management groups for agricultural purposes. The first half of the circular deals with how and why soils differ, how they are grouped into soil management groups, and general management practices that apply to all soils. It includes information on minimum tillage, correction of soil acidity, choice of adapted cropping systems, erosion control, and fertilizer recommendations. The second half of the circular gives specific recommendations for sets of soil management groups. The kinds of information given for each set of management groups includes: description of the soils, management problems, crop adaptations, erosion control, fertilizer recommendations, drainage recommendations and the average crop yields expected with the recommended management practices. This circular is intended to give soil management information on soils of the southern two-thirds of the counties in the lower Peninsula of Michigan.

This circular was used as one of the sources of information to be tested for its effectiveness in communicating soil survey and soil management information in a subsequent section of this investigation.

The Problems of Communicating Soil Survey Information

The great and increasing wealth of information available in the form of soil surveys and soil management information and the ever expanding uses of soil survey information might lead to the assumption that soil survey information is being readily used by large numbers of people. This assumption may not be true, particularly if viewed in the perspective of the total number of people who could profitably make use of this kind of information. It is entirely possible that the large volume of assembled material may actually inhibit the use of the soil survey information by potential users when they are confronted with the formidable task of reading and interpreting this information.

Mawby and Haver (1961) discuss the uses of different sources of information by farmers. Their study indicated that of 24 sources of information 6 were classified as non-communicative or those which can be used without contacting another person, and 18 were communicative, those that require that information be passed from one person to another. The most used source of non-communicative information was their own past experience while in this group the most used source of new technology was observed experience of others. The importance of communication through observation emphasizes the usefulness of educational techniques such as test demonstration farms, exhibits, and farm tours in communicating agricultural information. Communicative sources of information on farm production were in the following order from the most to the least used: (1) farm magazines, (2) agricultural agents, vocational agriculture teachers, and agricultural college representatives, (3) experimental and extension service publications.

These findings suggest that more effective communication of soil survey information might be accomplished through the use of soil maps and pertinent management information in conjunction with farmer field days at agricultural experiment stations. This would permit the relating of the soil maps to the actual soil patterns and landscape of the map area which are features that farmers observe on their own farms.

Sorenson (1957) stresses that new learning for an individual must be based on facts he already knows and therefore technological information for farmers should be based on their current state of knowledge. He found that formal education had the greatest relationship to soils knowledge and that increased schooling resulted in the best knowledge and understanding of soils. This increased soils knowledge resulted not only from the formal education but also from the impetus it gave to continued learning throughout subsequent years. Better than average knowledge of soils was also related to farmers who often made contact with county agents and those who were avid farm magazine readers. Recommendations suggested by the study included the suggestion that soil information should be based on soil concepts already understood by farmers and that most farmers need better information about special fertilizers, plant food requirements, and fertilizer needs of different soil types. It also showed that extremely poor understanding of the concept of soil pH as a measure of acidity was a problem with most farmers. The study concludes that new technical soils information that exists in a complex form should be broken down into separate ideas in order to present it in a form that is compatible with the background information of farmers.

Lionberger (1960) in his review of literature of research on the adoption of new agricultural practices discusses five stages often involved in the adoption of new practices by farmers. All of these (awareness, interest, evaluation, trial and adoption) involves the acquistion of information from various sources. Mass media such as newspapers, radio, television, and magazines are the major sources of communication at the awareness stage. At the interest stage other farmers and various agricultural agencies are important sources of information in addition to the mass media enabling the individual to evaluate the practice. During the trial stage, particularly where complex practices are involved, the county agricultural agent, vocational agriculture teacher, and other professional specialists are called on as sources of information. Finally, in the adoption stage of an agricultural practice a farmer may turn to government agencies or industry to obtain research information to facilitate his maximum use of that practice. The different kinds and sources of information needed at the five stages seem to indicate that persons wishing to communicate soil survey information should be prepared to present it in different forms to meet the needs of farmers in each of those stages.

Galloway (1966) described an educational approach to use of soil surveys in urban development being used in Indiana. Rapid urban growth in recent years has spurred the interest in use of soils information by persons interested in sound planning of area development. It was learned that urban people, unlike farmers, did not have sufficient contact with the soil to develop an appreciation for its characteristics and features. Extension personnel and soil conservation individuals initiated a teaching program to reach groups of individuals such as community planners, developers associations, watershed sponsoring groups, highway departments and other public officials. The program stressed usefulness of soil survey and soil management information in application to these persons problems. Teaching at the "awareness phase" used techniques that had been successful in education of agricultural groups. These included use of soil monoliths, colored slides, concise graphic soil descriptions, and block diagrams that relate soils to their parent material and topography. Sources of information were selected to permit persons to relate soil features to the soils and landscapes of their own communities. The report points out that Indiana is in the process of shifting from the awareness phase of communication to the action phase in which persons are being trained in the use of soil survey information. Two facts became clear at this stage: (1) soil maps are complicated, hard to orient to, and difficult to understand, and (2) that reports are highly descriptive, too lengthy and not well 'user oriented' for most effective communication of this type of information. To teach better understanding of the use of soil maps, interested individuals were encouraged to work problems in which they had to use the information obtained from soil maps. This was done at extension meetings where assistance was available for answering questions and assisting with problems that arose. Simple demonstrations and slides were used to help people understand basic soil properties, such as water storage, and soil drainage that are important to urban uses of soils information.

Lessons learned from this program seem to the present author to confirm the need for different sources of soil survey information aimed at the different stages of understanding of users. They also suggest that the standard soil survey report is ineffective as a source of soils information for inexperienced individuals needing it unless assistance from persons familiar with its content and arrangement is available.

Bidwell and Bohannon (1960) in describing the promotion of the use of a soil survey in Saline County, Kansas, also stress that communication of soil survey information is more than the simple handing out of a soil survey report. In order to get the most effective use of a newly published soil survey report the following steps were used: (1) awareness was created through the use of the mass media, radio and newspapers, (2) interest was aroused through letters sent out by the county extension agent, feature newspaper articles and editorials, and news articles given over the radio, and (3) education in the form of community meetings. At these a soil scientist described soil properties, a conservationist discussed the importance of good land use and treatment, and an agronomist discussed the relation of soils to soil management and soil testing. The meetings included instruction of individuals in the use of the soil maps and interpretation of the soil management information contained in the report. Follow-up meetings were suggested to help farmers consider needs and problems in use of the survey, to outline procedures to fit surveys to their particular needs, and the development of long range plans for adopting recommendations made in the surveys.

Conclusions drawn from these experiences tend to parallel those of the Indiana use of soil surveys for urban planning and illustrate the need for various sources of information to meet demands as people become aware of, are interested in, and participate in the use of soil survey information. It is also evident that education of potential users is important to maximize the effectiveness of soil survey reports in communicating the information contained in them.

An excellent research study done by Parsey (1957) investigated the "Use and Usefulness of a Simplified Soil Survey Report." The soil survey report "Get the Most from Your Farmland" (Porter, et al, 1955) was prepared for use by farmers in Odessa Township, Ionia County, Michigan. The content of this interim soil survey report (described previously in this literature review) was presented in a simplified and popularized form for ease of reading and dealt entirely with agricultural interpretations. The report was distributed to 194 Odessa Township farmers in June 1955. Forty-three of these were interviewed 5 months later with regard to their use of the report. Information obtained from the interviews, was used to answer the questions: (1) will farmers use the report? (2) can farmers use the report? and (3) what values do farmers see in the report? It was learned that 67% of the farmers "looked" at the report but that only 14% of them "studied" it. Of the 43 farmers interviewed only 7 had "studied" the report and 6 of these had done so at an extension meeting at which the report had been discussed. The study concluded that a maximum of

58% of the farmers might be expected to look at or use the report if it was simply given to them.

In answer to the question, can farmers use the report, the research indicated a dual situation existed. What farmers said about using the report, and what farmers were actually able to do in terms of performance in using the report differed markedly. Of the 43 farmers interviewed 29 had looked at the report and of these only 17 said that it was easy to follow. Detailed investigation revealed that 10 of these had some difficulty in following the report despite the fact that 15 of the 17 had received some help in going through the report. On the average, farmers made five errors out of a possible 12 steps in using the report. It was found that farmers given assistance by a county agent or a person familiar with the report did considerably better than those without assistance. This indicated that even a minimum amount of education is highly beneficial in the use of this type of information. Information learned regarding the value of the soil survey report shows that about one fifth of the farmers said that they had actually used the report, that more than one third said that they plan to use material in the report, that about one third said they found the report not difficult to use and about one half said they had learned something new from the report. About two thirds of the farmers who had looked at the report agreed with the general recommendations included in it which suggests that this relatively large proportion of farmers regarded the report as an authoritative document on soil management.

It was found that technical terms contained in the report were difficult for farmers to understand and use, and that chemical terms associated with lime and fertilizer were words "without meaning." Straightforward crop yield tables were easy for farmers to use while the more complex ones suggesting crop rotations were more difficult. Lime and fertilizer tables were found to be the most difficult to use. Conditions considered necessary to make this report an effective communication tool were: (1) that farmers must be interested or become interested in soils, (2) the report itself must build on knowledge which farmers previously had about soils, (3) the report must be studied closely enough to make its contents understandable, and (4) assistance, explanation, and stimulation must be available both for understanding the report and for carrying out its recommendations.

TRIAL AND EVALUATION OF THE 1962 "KNOW YOUR SOILS AND HOW TO USE THEM"

Introduction

Modern agriculture is becoming increasingly dependent on the use of soil survey and management information for efficient production. The number of soil surveys and the quantity of scientific management information is being increased to meet this need. The state of Michigan itself has four counties with modern surveys published and eleven in process of publication.

In soil science we are faced with the problem of disseminating this soil survey information, with related research results, to those people who can use it and to do so in a form that is both accurate and readily understood. For a farmer this involves use of: (a) a soil map to identify the soils on his farm and (b) specific management information for his particular soils and farming operation.

Some problems presently occurring in use of soil survey information are: (1) farmers using modern soil survey reports must study voluminous material that includes much information which is not of use to them, (2) in many counties where mapping is in progress or already completed the survey report is not available, with the narrative management information, for periods ranging from 4 to 7 years, (3) several counties have old soil survey reports with useful soil maps but obsolete management recommendations.

A soil management circular, "Know Your Soils and How to Use Them," was written in 1962 to bring together specific recommendations and predictions about the soils and agriculture of Michigan.

One of its important functions could be to help solve the previous problems in use of soil survey reports. The circular is an outgrowth of the Soil Survey Summary for Odessa Township (An Interim Report) prepared in 1955 with the assistance of the National Project in Agricultural Communications. It was written with the benefit of research findings (Parsey, 1957) that pointed out weaknesses and needed improvements in the Odessa Report. The major objective of the study was to determine how effectively the circular could be used with soil maps as a basis for management of soils for agricultural purposes and what could be done to increase its effectiveness.

A. Field Trial of the 1962 "Know Your Soils and How to Use Them"

The field trial consisted of distribution of "Know Your Soils and How to Use Them," hereafter referred to as "Know Your Soils," to a group of agricultural extension agents who were given a brief explanation of the content and purpose of the circular. These men were asked to aid in its evaluation in terms of its effectiveness as a source of soil management information.

This part of the study was conducted to determine the following: (1) ways to use the circular, (2) groups who would benefit from its use, (3) organizational changes that could improve its effectiveness, (4) terms, phrases, or information that should be added or deleted, and (5) problems encountered in its use.

The eleven county agents invited to participate in this study were selected on the following bases: three were in counties with modern recently published surveys, one was in a county with the mapping completed but the survey report unpublished, three were in counties with surveys in progress and the mapping nearly complete, and four were in counties with older published maps at a 1 inch = 1 mile scale and limited acreages of modern mapping for Soil and Water Conservation Plans in Soil Conservation Districts. All agents selected had shown considerable interest in using soil survey information in their extension programs.

They were invited to a meeting June 20, 1962 following the annual Michigan County Agent Association Meeting at Michigan State University. At that time the "Know Your Soils," circular was distributed and its contents and arrangement briefly explained. The agents were given 20 to 30 copies for trial use in their respective counties. They were asked to read the circular and to use it for any purpose useful in their county extension programs.

Interviews. All agents were then interviewed during the period August 3 to September 25, 1962. Prior to the interview each agent was sent the following list of topics to be covered in the interview.

1. Should this circular be accompanied by soil monoliths and wall charts that could be displayed in prominent places to stimulate interest?

2. In what way or ways do you use the circular?

3. What terms or phrases do you think users of this circular might not understand or find confusing?

4. How might the organization of the circular be changed to increase clarity or ease of use?

5. Does the circular contain too much information (information that is not useful to you)?

   a. If so, what material should be omitted?

6. Is there additional information that you would like to have included?

   a. If so, what materials would you like to have included? or

b. What questions should be answered?

7. Would you like a training session?[1]

The interview responses are summarized in Table 1. As a result of the interview responses, in which agents expressed a strong interest in having a training session on the background, content, and thorough understanding of "Know Your Soils," it was decided to set up a two-day seminar.

B. Training and Evaluation Seminar for County Agents on "Know Your Soils"

A two-day seminar on the content and use of "Know Your Soils" was held January 14-15, 1964. The first objective was to give agents a confident understanding of the content and organization of the circular. This included: (1) knowledge of the characteristics and classification of Michigan soils, (2) organization and meaning of soil management groups and their symbols, (3) general knowledge of soil management practices applicable to all southern Michigan soils as given in the yellow section of the circular, and (4) an understanding of organization and general content of soil management information as applied to specific sets of soil management groups. The second objective was to have the agents develop skills in using soil maps in conjunction with "Know Your Soils" to determine management practices for specific areas and determine kinds of problems encountered in this procedure. The third objective was to determine improvements needed

[1]This was suggested by the first agent interviewed and was included in all subsequent interviews.

Table 1. Summary of kinds of interview responses concerning agent use of "Know Your Soils."

Question 1 - Soil monoliths to arouse interest

1. Yes, if inexpensive
2. No for interest but useful as teaching aid
3. No for interest - farmers already interested in soils

Question 2 - Use of circular

Uses tried	Uses suggested
1. Reference for vocational agriculture young farmer schools	1. High School vocational agriculture source material
2. Extension soils school for farmers	2. In conjunction with soil testing program
	3. Handout bulletin to farmers with explanation of use

Question 3 - Confusing terms or phrases

1. Technical terms not understood (glossary necessary)

Question 4 - Organization improvement

1. White section as fly sheets for handout singly as needed
2. Shorter paragraphs
3. Printed rather than mimeographed
4. Include table of contents

Question 5 - Too much information?

1. No agent said too much information was in the circular
2. Loose leaf form suggested so agent could give a farmer only those sections needed for his soils and operations.

Question 6 - Additional information suggested

1. Differences among liming materials
2. Soil test interpretations as influenced by manure applications

Question 7 - Need for training session

1. Almost unanimously, yes.

in material and organization of "Know Your Soils" for increasing effectiveness.

Seminar Program

The total program was designed to give background information, a thorough coverage of the content and organization of "Know Your Soils," and experience in using the circular. Six county agricultural extension agents participated in the entire seminar.

Subject matter emphasis. The informational aspect of the program was covered in three sessions. The first was devoted to review of findings resulting from the trial of "Know Your Soils" and discussion of soil differences, classification, and management grouping of Michigan soils. The second dealt with soil management practices as related to fertility, tillage and erosion control. The third with organization and general content of "Know Your Soils" followed by a discussion, summary, review of the seminar, and plans for possible changes to be incorporated in a revision of "Know Your Soils."

Workshops. The seminar included two workshops for developing skills and determining problems encountered in working a typical management problem. In the first workshop the agents were given legal land descriptions to locate a tract of land in each of two soil survey reports. Each tract, after being located, was circled in pencil on the map, its map sheet number and the soil mapping unit symbols of all soils in the tract were recorded. Using the mapping unit symbol and map legend the agents determined the soil type name, soil management group, slope class, and erosion class for each of the soils in the tract. Table 2 is an example of the form used to record the information.

Table 2. Workshop #1, problem form.

On the attached soil map and "Know Your Soils" circular:

a) Locate the following tract and bound it with a pencil line: T___N, R___E, Sec.____, ______160, ____40 in _____ Township of __________ County.

b) Fill out the following table completely for the tract in a).

Mapping unit symbol	Soil name	Soil management unit		
		Soil management group	Slope class	Erosion class

Three of the agents worked their problem from the Sanilac Survey (1961) which has 4 inch = 1 mile scale maps while the other three agents were given the Lenawee Survey (1961) which has maps at a 3.17 inch = 1 mile scale. Each agent recorded the length of time needed to complete his problem. Each group was subsequently given the other report and problem and again asked to record the time for completion. A comparison of time length needed by each agent to complete each report is given in Table 3. All agents took more time to complete the first problem than the second, regardless of which survey was used first. The mean decrease in time was the same for both groups which would tend to indicate that length of time needed for completion of problems was related to amount of skill developed rather than differences in difficulty of use of one report compared to the other.

Table 3. Summary and comparison of the time needed for completion of the problem using both Sanilac and Lenawee Soil Survey Reports.

Agent	First problem	Second problem	Difference from first to second problem
1	20 min. Lenawee	12 min. Sanilac	-8 min. Lenawee to Sanilac
2	13 min. Lenawee	9 min. Sanilac	-4 min. Lenawee to Sanilac
3	27 min. Lenawee	20 min. Sanilac	-7 min. Lenawee to Sanilac
Mean	20 min.	14 min.	-6 min.
4	13 min. Sanilac	9 min. Lenawee	-4 min. Sanilac to Lenawee
5	16 min. Sanilac	8 min. Lenawee	-8 min. Sanilac to Lenawee
6	15 min. Sanilac	8 min. Lenawee	-7 min. Sanilac to Lenawee
Mean	15 min.	8 min.	-6 min.

The problem sheets were graded and errors were tabulated, Table 4, as to their kinds, frequency of occurrence, and the number of agents making each. The most frequent error was the failure of agents to recognize that the lowest erosion class in the Lenawee Report was 0 or 1. Agents made the error of indicating only one of the numbers.

At the completion of the two problems, the agents were given the following questionnaire on which to list features which caused difficulty in the use or understanding of each report and to note feature preferences in each report, Table 5.

In the second workshop the agents were given legal land descriptions to locate a tract of land and identify its soils, as in workshop #1, (items a and b, Table 2) and in addition they were to

Table 4. Summary of errors incurred in the use of soil map information from Sanilac and Lenawee Soil Survey Reports used in workshop #1.

Kind of problem or errors	No. agents making error	No. times error made
Wrong soil type name for mapping unit symbol	1	1
Wrong management group symbol for mapping unit symbol	1	1
Included slope class in management group symbol	2	7
Located wrong map area	1	1
Omitted textural class in soil type name .	1	1
Indicated wrong erosion class	1	1
Indicated wrong slope class	1	1
Wrong map page (used number of adjoining sheet at bottom of map)	2	2
Included map unit that did not occur within area	1	1
Failed to use 0 or 1 where this erosion class occurred in Lenawee County	4	12

determine answers to management problems using information in "Know Your Soils." Agents used soil maps of their respective counties, two of which were modern published surveys on aerial photo bases, three were air photo sheets containing recent mapping with accompanying legend and one a 1938, 1 inch = 1 mile scale published survey. Only two errors were made in the recording of this information as compared to an average of 14 errors per report recorded for the same items in the first workshop. This indicates that the agents

Questionnaire #1

Name ______________________________

1. Please make a list of any features in the first Soil Survey Report that you had that made it difficult to use or hard to understand.

   Name of Soil Survey: ____________________

   Features:

2. Repeat question #1 for the second Soil Survey Report.

   Name of Soil Survey: ____________________

   Features:

3. Which Soil Survey do you prefer, and why?

Table 5. Summary of difficulties in use of the Sanilac and Lenawee Reports and features preferred in each.

No. of complaints	Difficulties in Sanilac Report
6	Difficult to locate townships on index map because of indistinct boundaries between townships and omission of township names.
4	Section numbers not given on Index to Map Sheets.
3	Map symbols, soil names and management groups not all in one place.
1	Arrangement of sheets (Maps from the North and South half of the county were on alternate facing pages of the map section of the report).
	Difficulties in Lenawee Report
1	Erosion class number omitted from map symbol when it is 0 or 1.
5	Range and town areas do not correspond with photos. (Except on the East and West sides of the county the township boundaries and map sheet boundaries never coincide).
4	Photo sheet numbers hard to find on map sheets. (They are folded in to the center of the report).
3	Index map does not give all section numbers. (Only sections 1, 6, 31 and 36 are numbered).
1	Fold out map sheets more difficult to use than single sheets.
1	Township names not shown on the Index to Map Sheets.
1	Town and range boundaries not clearly shown on the Index to Map Sheets.
	Features preferred in the Sanilac Report
4	Larger scale, less area per sheet.
1	Erosion factor given on all units.
3	Single map sheet (unfolded).

Table 5. (concluded)

No. of complaints	Features preferred in the Lenawee Report
2	Index map has section numbers in corner of townships and more distinct tick marks between townships.
3	Included all legend information (series, slope, erosion and management groups) in one place (Guide to mapping units).
1	More sections per page of maps.

increased their skill in the location of a tract of land and identifying the soils on that tract as a result of the experience gained in the first workshop.

"Know Your Soils" was used as the source of soil management information. Agents were asked to identify the most sloping well-drained soil management unit which they had listed. The problem also required that they locate information on lime requirement, fertilizer requirement, cropping systems (rotation), and expected yield for the above soil, and to indicate which of the soils listed might need artificial drainage. A copy of the (c-e) items of the workshop problem and the number of agent errors for each are given in Table 6.

Two of the four incorrect answers on lime requirement for alfalfa were values of the range $1\frac{1}{2}$-$2\frac{1}{2}$ tons rather than the specific value $2\frac{1}{2}$ tons that would be needed for pH 5.5. The high number of incorrect answers to item c3) suggests that use of the information in the erosion control section is difficult to interpret accurately or that agents have had little experience in this aspect of soil management. Two of the three incorrect answers dealing with yield of alfalfa

Table 6. Summary of agent errors for soil management problem.

Problem Items c-e	No. of agent errors
c) Recommend for the most sloping well-drained soil management unit what would be:	
(1) Its lime requirement per acre for seeding alfalfa if its surface pH is 5.5	4
(2) The fertilizer nutrients needed if the soil test shows 40 lbs. of P and 120 lbs. of K (using 1 N NH_4Ac, in the State Laboratory)	2
(3) What is the least protective cropping system recommended, if minimum tillage is used on this soil	5
d) What yield of alfalfa would you expect on this soil in c) with the recommendations you have given?	3
e) If no artificial drainage has been supplied to this forty acres, is any required for success of the alfalfa seeding? If so, on what soil management group? . .	1

(item d) seemed to indicate that the agents were estimating yield on a basis of their personal experience rather than on data taken from "Know Your Soils" as the values given had no discernible relation to those in the circular. The relatively high score on (item e) indicatesthat agents are aware that soil management groups containing "b" or "c" in their symbol are naturally not well drained and probably would need artificial drainage.

Evaluation. Agents were pretested at the beginning of the seminar and posttested at its conclusion to evaluate the effectiveness of the seminar in communicating soil management information. The test used, Appendix B, covered five areas of information, sections I-V, as follows: I--general information on all phases of "Know Your Soils," II--soil classification and its symbols, III--management group symbols, IV-A, B, C--content and organization, and V--definition of key terms.

A summary of the pretest and posttest results is given in Table 7. The mean increases in test scores ranged from 13% to 31% on the various sections. These were statistically significant at the .05 level using Wilcoxon's[2] test for paired replicates, with the exception of the increase in section II which was not significantly greater at the .05 level. The wide range in score changes, including a decrease in the score of one agent, and no change in the score of another, probably accounts for the lack of a significant difference in this section. Actually the score of three agents increased 29%.

In section I the greatest percentage increase occurred in items 1, 5, and 13 (Table 8). The increase in item 1 concerning the index map of a soil survey probably reflects the agents involvement with this information in the workshop. Item 5 deals with soil series and type and its 66% increase may best be explained by the fact that not only was it covered in lecture but also through dealing with this information in the workshop. The 33% increase in item 13 represented increased knowledge on the content of "Know Your Soils."

All agents gave correct answers on both pretests and posttests for items 6-10 and 15. These items deal with information that one would expect agents to be familiar with from their work experiences.

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[2]Wilcoxon, F. Some Rapid Approximate Statistical Procedures, New York, American Cyanamid Co., 1949, p. 13, quoted in Virginia L. Senders, Measurement and Statistics, New York, Oxford University Press, 1958, 489-491.

Table 7. Summary of county agent scores for pretest (1), posttest (2), and change (△), taken during "Know Your Soils" seminar.

		Test section																							
		I			II			III			IV-A			IV-B			IV-C			V			Total test		
		15 points			7 points			8 points			6 points			5 points			6 points			15 points			62 points		
Agent		1	2	△	1	2	△	1	2	△	1	2	△	1	2	△	1	2	△	1	2	△	1	2	△
1	pts	11	13	2	5	4	-1	4	6	2	3	4	1	0	3	3	3	6	3	8	11	3	34	47	13
	%	73	87	14	71	57	-14	50	75	25	50	67	17	0	60	60	50	100	50	53	73	20	55	76	21
2	pts	8	11	3	1	3	2	3	4	1	4	5	1	5	5	0	6	5	-1	4	10	6	33	45	12
	%	53	73	20	14	43	29	38	50	12	67	83	16	100	100	0	100	83	-17	27	67	40	53	72	19
3	pts	9	11	2	4	6	2	4	5	1	3	3	0	5	5	0	5	4	-1	4	9	5	34	43	9
	%	60	73	13	57	86	29	50	63	13	50	50	0	100	100	0	83	66	-17	27	60	33	55	69	14
4	pts	11	12	1	4	4	0	2	5	3	2	5	3	3	5	2	2	5	3	6	8	2	30	44	14
	%	73	80	7	57	57	0	25	63	38	33	83	50	60	100	40	33	83	50	40	53	13	48	71	23
5	pts	10	12	2	5	7	2	4	7	3	3	5	2	3	5	2	3	5	2	6	13	7	34	54	20
	%	67	80	13	71	100	29	50	88	38	50	83	33	60	100	40	50	83	33	40	87	47	55	87	32
6	pts	10	12	2	3	4	1	3	6	3	5	4	-1	3	5	2	2	5	3	8	12	4	34	48	14
	%	67	80	13	43	57	14	38	75	37	83	67	-16	60	100	40	33	83	50	53	80	27	55	78	23
Mean	%	66	79	13*	57	71	14	42	69	27*	55	72	17	63	93	30	58	83	25	39	70	31*	54	76	22*
	IV-A, IV-B, IV-C combined													59	82	23*									

*Significant at .05 level.

Table 8. Evaluation for county agent group from pretest to posttest on test section I (true and false on overall information) in the "Know Your Soils" seminar.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
1	50.0	16.7	00.0	33.3	+33.3
2	66.7	16.7	00.0	16.7	+16.7
3	16.7	50.0	16.7	16.7	0.0
4	0.0	66.7	16.7	16.7	0.0
5	33.3	0.0	0.0	66.7	+66.7
6	100.0	0.0	0.0	0.0	0.0
7	100.0	0.0	0.0	0.0	0.0
8	100.0	0.0	0.0	0.0	0.0
9	100.0	0.0	0.0	0.0	0.0
10	100.0	0.0	0.0	0.0	0.0
11	16.7	66.7	0.0	16.7	+16.7
12	50.0	33.3	0.0	16.7	+16.7
13	33.3	33.3	0.0	33.3	+33.3
14	83.4	0.0	0.0	16.7	+16.7
15	100.0	0.0	0.0	0.0	0.0

	Pretest	Posttest	Change
Mean % correct	65.5	78.9	+ 13.4
Mean test score	9.8	11.8	+ 2.0

The average posttest score on this section was 78.9% an increase of 13.4% over the pretest score.

Section II deals with information that can be obtained from the soil name, mapping unit symbol and management unit symbol. Items 19 and 22 (Table 9) had 83.4% and 66.7% correct answers respectively in the pretest and both had 100% correct in the posttest. This indicates that most of the agents were familiar with the symbols for slope classes and the soil limitations of the management groups. Those who weren't, learned this information during the seminar. Four of the seven items in this section had one or more agent replies which decreased between pretest and posttest. This would seem to indicate that the seminar and "Know Your Soils" were inadequate in clarifying the kind of information that is important in the identification of surface texture, natural drainage, and soil series. There was an increase of 14.3% in scores between pretests and posttests on this section. The average posttest score was 71.4%.

Section III, on the system of management group symbols, had a 27.1% increase (Table 10) in scores between pretest and posttest and the average posttest score was 68.7%. All items showed increases ranging from 16.7% to 50.0% except item 27 which had no net increase and five of the six agents got it incorrect in both pretests and posttests. The soil in item 27 was described as a poorly drained soil with 11 inches of sand over bedrock. Agents used the symbol 4/Rc which would be correct if the sand was 18" to 42" thick but in situations where sand is less than 18" thick the management group symbol is Rc. Thus, the mistake is understandable. Item 24 dealing with a

Table 9. Evaluation for county agent group from pretest to posttest on test section II (soil classification and its symbols) in the "Know Your Soils" seminar.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
16	50.0	33.3	16.7	0.0	-16.7
17	0.0	66.7	0.0	33.3	+33.3
18	50.0	0.0	16.7	33.3	+16.6
19	83.4	0.0	0.0	16.7	+16.7
20	50.0	0.0	16.7	33.3	+16.6
21	16.7	16.7	33.3	33.3	0.0
22	66.7	0.0	0.0	33.3	+33.3

	Pretest	Posttest	Change
Mean % correct	57.1	71.4	+14.3
Mean test score	4.0	5.0	+ 1.0

Table 10. Evaluation for county agent group from pretest to posttest on test section III (management group symbols) in the "Know Your Soils" seminar.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
23	83.4	0.0	0.0	16.7	+16.7
24	0.0	83.4	0.0	16.7	+16.7
25	50.0	0.0	16.7	33.3	+16.6
26	50.0	0.0	0.0	50.0	+50.0
27	16.7	83.4	0.0	0.0	0.0
28	50.0	16.7	0.0	33.3	+33.3
29	33.3	16.7	0.0	50.0	+50.0
30	33.3	33.3	0.0	33.3	+33.3

	Pretest	Posttest	Change
Mean % correct	41.6	68.7	+27.1
Mean test score	3.3	5.5	2.17

miscellaneous land type, Lake Marsh, in the Sc management group, was also missed by five of six agents in both pretests and posttests.

Section IV-A, B, and C had increases in correct answers of 17%, 30%, and 25%, respectively, Table 7. Section IV deals with location of information in the circular that would facilitate its use. Items 31 and 33 (Table 11) showed decreases of -16.7% and -33.3%, items 35, 42, and 45 showed no net increase. However, there was a perfect score on item 45 in both tests. All other items had increases in scores of from 16.7% to 66.7%. The average increase in scores was 23.6% and the average posttest score was 82.4%. Results of this section show a significant increase by agents of knowledge concerning informational content and arrangement of topics in "Know Your Soils" resulting from the seminar. The items with which they were most familiar and for which they had other sources of information, such as fertilizer recommendations (33, 35, 42) were apparently of least interest to the group.

Section V consisted of definitions of key terms used in the circular. All items showed net increases ranging from 16.6% to 50.0% per item with a mean increase of 31.3% for the section (Table 12). The average posttest score was 70.0%. Thus, it can be concluded that the seminar and workshop had significant beneficial effect on agents understanding of key terms used in "Know Your Soils."

Table 11. Evaluation for county agent group from pretest to posttest on test sections IV-A, B, C (content and organization) in the "Know Your Soils" seminar.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section IV-A		
31	66.7	16.7	16.7	0.0	-16.7
32	66.7	0.0	0.0	33.3	+33.3
33	16.7	16.7	50.0	16.7	-33.3
34	16.7	16.7	0.0	66.7	+66.7
35	50.0	16.7	16.7	16.7	0.0
36	33.3	16.7	0.0	50.0	+50.0
			Section IV-B		
37	83.4	0.0	0.0	16.7	+16.7
38	83.4	0.0	0.0	16.7	+16.7
39	83.4	0.0	0.0	16.7	+16.7
40	33.3	16.7	0.0	50.0	+50.0
41	33.3	16.7	0.0	50.0	+50.0
			Section IV-C		
42	16.7	50.0	16.7	16.7	0.0
43	66.7	0.0	0.0	33.3	+33.3
44	33.3	16.7	16.7	33.3	+16.6
45	100.0	0.0	0.0	0.0	0.0
46	50.0	0.0	0.0	50.0	+50.0
47	50.0	0.0	0.0	50.0	+50.0

	Pretest	Posttest	Change
Mean % correct	58.8	82.4	+23.6
Mean test score	10.0	14.0	+ 4.0

Table 12. Evaluation for county agent group from pretest to posttest on test section V (definitions) in the "Know Your Soils" seminar.

Item No.	Percent correct pretest	Percent correct posttest	Percent change
48	33.4	66.7	+33.3
49	16.7	66.7	+50.0
50	55.6	83.4	+27.8
51	61.2	77.8	+16.6
52	27.8	55.6	+27.8

	Pretest	Posttest	Change
Mean % correct	38.7	70.0	+31.3
Mean test score	5.8	10.5	+ 4.7

Discussion, Summary and Review

The county agent training seminar was concluded with a summary, discussion and review of material covered. Suggestions for the improvement of "Know Your Soils" and Soil Survey Reports included the following:

1. A glossary and index added to the circular.
2. The circular organized such that sections could be used independently as separate handout sheets or together as the total circular.
3. Information to be added in the circular should include:
    a. A general section on minimum tillage and specific recommendations for sets of management groups.
    b. Lime recommendations to incorporate information on plowing depth as it affects lime requirement.
4. Improvements needed in organization of soil survey information and maps to make them more useable for soil management purposes.

Summary and Conclusions

The field trial of "Know Your Soils" and the subsequent county agent training seminar indicated that the circular contained information that would be useful to numerous persons needing soil management information. The circular was found to be an effective source of management information when used with county agents within the framework of a seminar and as measured by pretesting and posttesting. The seminar was a necessary and effective adjunct to the "Know Your Soils" circular for this group of agricultural leaders.

Its usefulness was reduced by problems encountered in obtaining needed soils information from soil surveys. It was found that the sequence of steps needed to determine management recommendations for the soils of a given land area poses many obstacles for the individual not skilled in the procedure. The following suggestions were made to reduce these difficulties and improve the effectiveness of "Know Your Soils" as a specific guide to management practices. When used with "Know Your Soils" the three areas in which improvement is needed in soil survey reports are: (1) readability of the Index to Map Sheets, (2) the labeling of map sheets, and (3) the Guide to Mapping Units needs to contain identity of mapping units and references to management groups for various purposes. More specific suggestions for the improvements needed are given in a letter prepared for the cooperative soil survey under date of March 24, 1964, see Appendix C.

It was concluded that the effectiveness of "Know Your Soils" as a source of useable soil management information would be increased if it could serve the dual functions of: (1) a complete bulletin serving as a concise source of the full range of management information on Michigan soils, and (2) a series of separate sheets or units that could be used singly or in various combinations to give a user a set of those units specifically related to his particular management situations and for his particular soils. A revision of "Know Your Soils" was planned as a result of the above findings with changes and additions incorporated to meet the suggested recommendations. This revision of "Know Your Soils" was completed in 1964.

REVISION OF THE 1962 "KNOW YOUR SOILS"

Introduction

"Know Your Soils" was revised in 1964 on the basis of the results and recommendations obtained from the trial use by county agricultural agents of the 1962 edition of the circular, a county agent training seminar on the content and use of "Know Your Soils," and the follow-up comments and suggestions from the participating agents. It was concluded that the effectiveness of the circular as a source of useable soil management information could be increased by reorganization, revision of the content for clarity and accuracy, and the inclusion of several additional topics.

Objectives

The overall objective of the "Know Your Soils" revision was to increase the circular's effectiveness as a means of communicating soil management and soil survey information to the largest number of potential agricultural users. Effectiveness of the circular could be increased by making it applicable to different groups of people with differing needs.

The first specific objective was to meet the needs of as many potential agricultural users as possible through the reorganization of the circular into separate units that could be made available in the following forms: (1) a total circular, (2) selected sections of the circular, or (3) a single section of the circular. County agricultural extension agents, vocational agriculture teachers, and conservation personnel needing a comprehensive coverage of soil management information would find the first form most useful. Farmers could benefit most by using selected sections that apply directly to their soils and management needs. The third form would be useful for distribution to individuals desiring specific information on one topic.

The second objective was to continually give users current accurate information by incorporation of the most recent agricultural research findings and organization of the circular to permit ease of future revision.

The third objective was to give users a more comprehensive coverage of soil management information by including several additional topics pertinent to soil management that had not been contained in the original "Know Your Soils" circular.

Organization of the 1962 "Know Your Soils"

The original "Know Your Soils" (Appendix F) consisted of a green cover, a yellow section (12 pages) containing general management information by topics, and a white section (24 pages) containing specific management information for sets of soil management groups. Use of the three colors was intended to give users ready identification of the major divisions of the circular. The inside front cover explained how the circular should be used.

Yellow section. This section included the following kinds of information: (1) how available soils knowledge can be useful for various purposes and to various groups, (2) how and why soils differ from one another, (3) how soils are grouped into soil management groups for the purpose of agricultural interpretations and uses, (4) how the properties of these soils are important to their use, and

(5) information on various management practices including short discussions on minimum tillage, weed control, correction of soil acidity, micronutrients, choice of adapted cropping systems, erosion control, good seed and fertilizer recommendations. The topics in the yellow section follow each other consecutively with only topic headings to separate them. The topic material was presented in a concise highly condensed form to keep the length of the circular to a minimum.

White section. This section contained specific recommendations for each specific set of soil management groups on two facing pages (pair pages) as illustrated on pages 14 and 15. It included information on the description of soil characteristics, management problems, crop adaptations, least protective cropping systems, fertilizer recommendations, drainage recommendations, average crop yields expected and other production and conservation practices for the set of soil management groups e.g. 1a, 1b, and 1c. The sets of management groups appear in numerical order, that is, group 1 soils first, group 2 second, etc., followed by the alphabetical groups Ga, Gc, L, etc., respectively.

The last white sheet (page 36) contained information on how soil maps are made and an explanation of how soils are named.

This white section made use of cross references within itself and to information in the yellow pages to prevent repetition of material and therefore give the maximum information with a minimum number of pages.

Organization of the 1964 "Know Your Soils"

In reorganizing "Know Your Soils" the attempt was made to incorporate suggestions made by the agricultural extension agents during and following the training seminar, the workshop evaluations, and the information gained from the pretesting and posttesting of agents that attended the "Know Your Soils" seminar.

Rearrangements. A major organizational change was the subdivision of the circular into independent sections, color coded with four additional colors for easy identification. Information on the front and inside of the front cover was retained unchanged from the "1962" version. The first major section, printed on green paper similar to the cover, dealt with soil maps, soil properties, soil management groups and soil sampling. Section two, printed on a goldenrod colored paper, dealt with soil tests and fertilization. Section three was the newly published (1964) bulletin 471, "Lime for Michigan Soils." Section four, (pale yellow) covered the general principles of minimum tillage. Section five, (pink) discussed soil erosion control: principles, practices, and recommended cropping systems.

The white section was reorganized into four page units, consisting of printing on two sides of each of two sheets. The first four page unit dealt with properties and management of the 0 (very fine) and 1 (fine) soil management groups. This two sheet (4 page) format was repeated for each following set of soil management groups. The four page unit or "pair sheets" arrangement had the advantage of easy removal for use as handouts. These sheets were completely independent and required no cross-references to "pair sheets" for other sets of management groups. It also permitted inclusion of more information on the characteristics, management, and erosion control for each set of management groups than was possible in the 1962 version.

All sheets in the 1964 "Know Your Soils" are punched to permit insertion into a looseleaf notebook and to facilitate the use of independent sections of the circular. Lower case letters were used to designate the pages of each section. The first page is (a), the second page (b), etc. This eliminated confusion when an individual had only certain sections of the circular. Another advantage of this alphabetic system of pagination for each section is that it permits additional units of information or topics to be inserted as they become available and are found to be useful inclusions in the circular.

Inclusion of additional information. The trial and evaluation of "Know Your Soils" indicated that additional information should be included in the circular to increase the subject content, clarify information already included in the circular, and to increase its readability. Information added in section one included a table of contents unanimously suggested by the county agents. The management groups 1.5 and 2.5 were added to the management group table on page 3. These two management groups were added because it was found that a separation of clay loam from loam profiles, which had both been previously included in management group 2, was necessary information needed in effective erosion control and in estimating productivity for various tree species. The page on 'How Soil Maps are Made' and 'How Soils are Named' was moved to the back of the Table of Contents in the green section from the last white sheet. This keeps it with the general introductory section instead of with one set of management groups.

Recommendations on how to collect soil samples for soil testing were added as a last page in the introductory green section. It was added to aid the increasing numbers of farmers and county agents using the soil testing service each year. Effective soil testing requires a careful collection of samples, and recording of the soil type name and plowing depth when this information is available.

The yellow section of the 1962 "Know Your Soils" contained approximately one page of information on correction of soil acidity. This information was replaced in the 1964 "Know Your Soils" with a six page extension bulletin No. 471 "Lime for Michigan Soils." The lime bulletin contains considerably more information with broader coverage of information on soil acidity, liming materials and soil liming needs. An important addition to the lime bulletin which had not been included in the 1962 "Know Your Soils" or in the previous lime bulletin was a graph from which it is possible to calculate the amount of lime necessary for plowing depths of 9 or 12 inches. The effect of plowing depth on lime requirement was recommended as an inclusion in the revised "Know Your Soils" by the agricultural extension agents.

Minimum tillage information in the original circular was revised and a figure added to illustrate the importance of plowing on pore space of soils. This general discussion was printed as a separate yellow sheet for inclusion in the revised circular. The topics, choice of adapted cropping systems and erosion control in the original circular were replaced by an independent section on principles and practices of erosion control and recommended cropping systems as a new pink colored section. It incorporated an entirely new approach to soil erosion control by using the universal soil loss equation to determine needed management practices for water erosion control. This had the advantage of increased accuracy as it was based on a large amount of experimental data (Wischmeier, 1960) and was more widely adaptable from state to state or area to area within a state. The section included definitions of the five factors in the universal soil loss equation and explained how the equation could be used to determine the conservation practices needed for erosion control. The five factors and their symbols are: (R) rainfall index, (K) soil erodibility factor, (LS) length and steepness of slope factor, (P) supporting conservation practice factor, and (T) allowable annual soil loss. Four tables were included to give the necessary data for determination of the cropping and management factor (C).

In the white section, profile diagrams representing a soil of each management group in the set were included on the first page (a) of each unit or "pair sheets." These profile sketches were added to illustrate the kinds of differences that existed in the profiles of these soil management groups in a diagrammatic form that users could compare to their soils. Space was provided beneath the profile sketches of each set of soil management groups for the user to write in the management units and the name of his soils belonging in these groups. The second page (b) contained specific information on minimum tillage practices that apply to the soil management groups contained in the unit in addition to information previously provided. On the third page (c) was information on fertilizer recommendations and productivities of the soil management groups. Erosion control information that applied to the sets of soil management groups was given on its fourth page (d). The additional information was inserted in each of the soil management groups to which it applied and the location of each topic was consistent within each of the "pair sheets."

Following the white section of the revised "Know Your Soils" a blue section was inserted containing a list of all Michigan soil series and their respective management groups to facilitate use of soil management information by users knowing the soil series on their farm. This information is also helpful for those individuals having older surveys with only the series name and not the management grouping or the more detailed slope and erosion separations shown on more recent maps. While the more recent maps are more detailed and more accurate the existing soils information should be utilized until better information is available.

The final section, also blue, was a three page glossary containing technical terms found either in "Know Your Soils" or needed to help in understanding soil survey information used in conjunction with the circular.

Review of accuracy of "Know Your Soils." Periodic revision of soil management bulletins is needed due to the continuing increase in crop yields and revised fertilizer or other management requirements commonly needed to accomplish this. During the revision of the 1962 "Know Your Soils," all recommendations of lime and fertilizer were reviewed for accuracy and expected individual crop yields checked against the most recent available information. Yield data and fertilizer recommendations were again altered for the 1964 "Know Your Soils" when necessary to agree with the latest research and yield estimates.

Lime recommendations, on the other hand, have changed less often as the pH and lime needs of various soils and crops has remained relatively constant. There has been improvement in methods for measuring lime requirement however in recent years. Thus, despite the fact that lime requirement recommendations contained in bulletins for Michigan soils have remained relatively constant over a considerable period of time it was felt advisable to attempt to determine whether these values were accurate relative to current lime recommendations based on the most recent lime requirement tests. This was done by obtaining the soil test records of soil samples analyzed in the Michigan State University soil test laboratory over a three year period. Soil texture, soil pH, and soil lime requirement (determined by chemical analyses) were recorded on IBM punch cards for each soil sample tested.

Considerable difficulty was encountered in obtaining the above information as a result of inadequate data recorded on the original data cards. As a result of the experiences gained during this lime requirement study a proposal, "Recommendations to the Michigan State Soil Testing Laboratory in regard to more effective use of soils information," (Appendix D) were prepared, with the assistance of Dr. John Shickluna, suggesting more adequate recording of important soils information relating to soil sample testing. The recommendations were organized to permit recording of information from any one of the following sources: (1) soil sample accompanied by its soil type name from modern soil surveys, (2) soil management group designation received with sample, (3) no information received with the soil sample.

In the last case the texture and presence or absence of a dark color in the sample, as estimated in the laboratory, are recorded. This type of information would be useful to aid in the interpretation of soil test results and valuable for research investigations.

All the IBM cards were grouped on a basis of soil texture and were further subdivided into the three following subgroups: (1) soils tested prior to April 1963 designated as light & dark (no distinction recorded between light and dark soil samples), (2) light colored soils tested after March 1963 representing normal or average field samples, and (3) dark colored samples tested after March 1963 representing soils abnormally high in organic matter.

The IBM cards of all subgroups of data were submitted to the Michigan State University computer center for regression analysis by the CDC 3600 computer. The regression analysis results (Table 13) were used to plot regression lines representing the relationship between pH and lime requirement for each of the subgroups. Values for plotting regression lines were obtained by substituting pH values into the regression equation $y = a + bx$. Lime requirement (y) is calculated for any desired pH value (x) and regression values (a) and (b) from Table 13. Regression lines were plotted using pH values of 4 and 6 and the corresponding lime requirement values. The dark colored, light colored, and light & dark samples of one textural class were plotted on each graph, where all were available, to show the relationship among them. An example is given in Figure 1. The dark colored samples for each of the textural classes had higher lime requirements than either the light colored samples or light & dark samples as indicated by the steeper slope of their regression

Table 13. Summary of regression analyses of lime requirement versus pH for various textural classes of samples tested in the MSU State Soil Testing Laboratory.

IBM Group No.	Plow layer Color	Plow layer Texture	No. of samples	Means: Lime requirement	Means: pH	Regression equation values: a	Regression equation values: b	r[1]
51	light	clay	13	3.23	5.88	20.38	-2.92	.7177
63	light & dark	sicl	7	1.86	5.80	8.76	-1.19	.6372
53	light	sicl	22	2.70	6.01	21.76	-3.17	.8076
64	light & dark	cl	14	1.89	6.09	10.57	-1.43	.4757
54	light	cl	181	3.16	5.94	23.33	-3.39	.7392
65	light & dark	loam	824	1.72	6.06	15.42	-2.26	.7031
55	light	loam	1242	2.35	6.02	19.76	-2.89	.7204
45	dark	loam	22	2.46	6.10	26.85	-4.00	.7977
66	light & dark	sil	95	2.71	6.03	17.06	-2.47	.8003
56	light	sil	39	3.45	5.85	21.64	-3.11	.6914
67	light & dark	sl	946	1.78	5.96	13.04	-1.89	.6373
57	light	sl	1176	2.40	5.93	19.94	-2.96	.7478
47	dark	sl	24	2.29	6.15	44.90	-6.92	.9222
68	light & dark	ls	592	1.67	5.95	13.12	-1.93	.6369
58	light	ls	918	2.05	5.94	19.72	-2.97	.7765
48	dark	ls	80	2.98	5.77	20.97	-3.12	.7661
69	light & dark	sand	206	1.81	5.81	10.49	-1.50	.4810
59	light	sand	274	2.08	5.87	19.66	-3.00	.7465
49	dark	sand	49	2.32	5.91	21.26	-3.21	.6915

[1]Values of (r) are corrected for degrees of freedom.

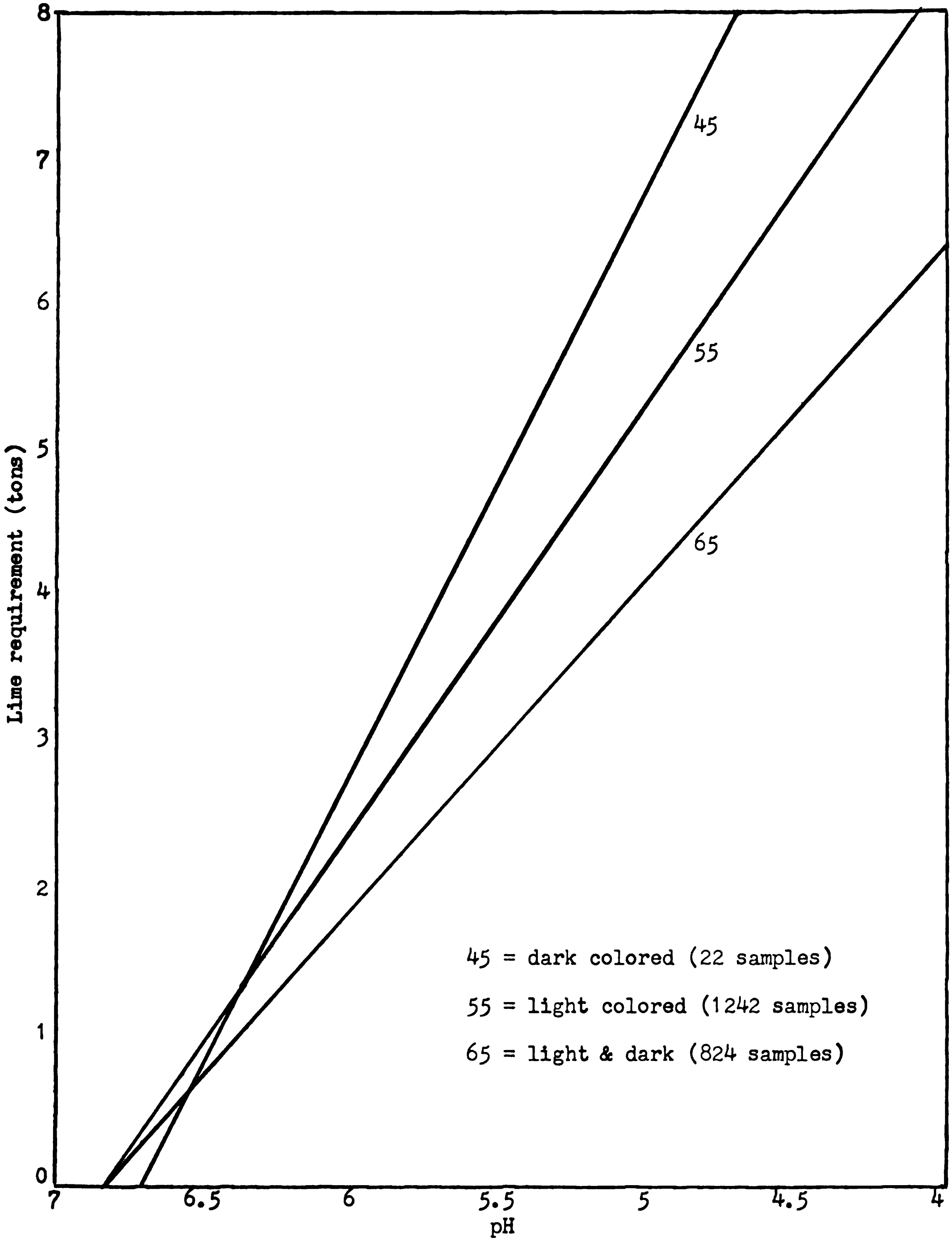

Figure 1. **Regression lines for lime requirement versus pH on three groups of loam samples.**

lines. This relationship is to be expected since a higher organic content, indicated by their darker color, would increase their exchange capacity and result in a greater lime requirement.

The light & dark samples tested prior to April 1963, containing both light and dark colored samples, had a regression line with a less steep slope than did the light colored soils tested after March 1963. This was true for all textural classes where the comparison could be made. This indicates that the difference was not caused by chance but is a consistent systematic variation. The lower slope of the line cannot be explained by the mixture of light and dark samples as this would tend to have the opposite effect, thus causing the slope to be greater than that for light colored samples. A second unusual relationship is that the difference between the slope of the regression lines for the light colored samples and the light & dark samples is, with one exception, as large or larger than the difference between the regression lines for the light colored and dark colored samples. It was concluded that the lower lime requirement of the light & dark samples as compared to light colored samples was caused by some factor other than organic matter content or related soil property.

A comparison of the lime recommendations contained in the 1962 "Know Your Soils," the 1964 "Know Your Soils," and the data compiled on lime requirements as determined by the Michigan State Soil Testing Laboratory using their presently accepted "buffer method," are given in Table 14. The County Soil Testing Laboratories are still using the 'pH's and textures' of the samples to determine lime recommendations.

Table 14. Comparison of lime requirements from 1962 "Know Your Soils," 1964 "Know Your Soils," and the "buffer method" from the MSU State Soil Testing Laboratory.

Topsoil texture	1962 "Know Your Soils" light colored[1]	1964 "Know Your Soils"	Soil test data: light & dark[2]	light[3]	dark[3]
	pH 4.5-4.9		pH 4.75		
Clay	5.5-6.5 (Clay–Clay loam)	6 (Clay–Silty clay)			
Silty clay					
Silty clay loam					
Clay loam		5 (Clay loam–Loam)		7.2	
Loam	4.5-5.5 (Loam–Sandy loam)		4.7	6.0	7.8
Silt loam			5.3	6.9	
Sandy loam		4	4.0	5.9	
Loamy sand	3.5-4.5 (Loamy sand–Sand)	3	4.0	5.6	6.1
Sand		2.5	3.3	5.4	6.0
	pH 5.0-5.4		pH 5.25		
Clay	4.5-5.5 (Clay–Clay loam)	5 (Clay–Silty clay)		5.0	
Silty clay					
Silty clay loam				5.1	
Clay loam		4 (Clay loam–Loam)		5.5	
Loam	3.5-4.5 (Loam–Sandy loam)		3.5	4.6	5.9
Silt loam			4.1	5.3	
Sandy loam		3	3.1	4.4	
Loamy sand	2.5-3.5 (Loamy sand–Sand)	2.5	3.0	4.1	4.6
Sand		2	2.6	3.9	4.4

Table 14. (concluded)

Topsoil texture	1962 "Know Your Soils" light colored[1]	1964 "Know Your Soils"	Soil test data: light & dark[2]	Soil test data: light[3]	Soil test data: dark[3]
	pH 5.5-5.9		pH 5.75		
Clay		4 (Clay–Silty clay)		3.6	
Silty clay					
Silty clay loam	3.5-4.5 (Clay–Clay loam)		1.9	3.5	
Clay loam		3 (Clay loam–Loam)	2.4	3.8	
Loam			2.4	3.1	3.9
Silt loam	2.5-3.5 (Loam–Sandy loam)		2.9	3.8	
Sandy loam		2.5	2.2	2.9	5.0
Loamy sand	1.5-2.5 (Loamy sand–Sand)	2	2.0	2.7	3.0
Sand		1.5[4]	1.9	2.4	2.8
	pH 6.0-6.4		pH 6.25		
Clay		2.5 (Clay–Silty clay)		2.2	
Silty clay					
Silty clay loam	1.5-2.5 (Clay–Clay loam)		1.3	2.0	
Clay loam		2.0 (Clay loam–Loam)	1.6	2.1	
Loam			1.3	1.7	1.9
Silt loam	1.5-2.5 (Loam–Sandy loam)		1.6	2.2	
Sandy loam		1.5[4]	1.2	1.5	1.7
Loamy sand	1.0-1.5 (Loamy sand–Sand)	1.0[4]	1.1	1.2	1.5
Sand		.5[4]	1.1	0.9	1.2

[1]Increase 50% for dark colored soils.

[2]Light & dark = light and dark samples tested before March 31, 1963.

[3]Light = light colored samples tested after March 31, 1963, and
Dark = dark colored samples tested after March 31, 1963.

[4]Use 2 tons per acre for uniform application.

If the lime requirements obtained from the soil test laboratory using the new "buffer method" are more correct estimates of soil lime needs than the previous procedure, then the lime recommendations given in Michigan bulletins to date underestimate lime needs of Michigan soils. This is particularly true at the lower pH's and on the coarser textured soils.

Probably the lime requirements given under the heading soil test data for light samples and dark samples should represent the most accurate values for use in future lime recommendation tables. Dark colored samples should be given separate recommended lime requirement values for a given texture and pH as these ranged from .5 ton to 2.1 tons greater than the requirements for corresponding light colored samples.

Soil tests prior to April 1963, and those still made by the 'pH and surface texture" method, give lower lime recommendations for all given textures and pH values despite the fact that those samples included some dark colored soils. Or expressed in another way, lime requirements given in the 1964 "Know Your Soils" were usually lower than those indicated by the recent soil test laboratory figures. The bulletin recommendations differed from the test data on light colored samples, Table 14, by as much as 2.9 tons per acre for sand textured soils to 2.2 tons per acre on clay loams at pH 4.5 to 4.9. The lime recommendations progressively increased from a minimum of 2.5 tons for sand to a maximum of 5 tons for clay loam at pH 4.5 to 4.9 based on pH and the texture of the plow layers. Laboratory data, on the lime requirement by the "buffer method," however, show increases from 5.4 tons for sand to a maximum of 7.2 tons for clay loam. The data indicate (Table 15) that higher rates of lime are not needed for those soils with finer textures than silt loams or clay loams and that clay loam and finer textures might be combined in lime recommendation tables as was done in the 1962 "Know Your Soils." Grouping of loam, with sandy loam, and of loamy sand with sand, also done in 1962 "Know Your Soils," seems justified from the data. The lime requirement for silt loams appear to be abnormally high in relation to the values for loam and sandy loam. This may indicate that most silt loams in Michigan are on the finer side of the silt loam textures.

Table 15. Recommended tons of limestone to raise the pH of a 6 2/3 inch plow layer of light colored samples to pH 6.5

Texture of the plow layer	Measured pH			
	4.5-4.9	5.0-5.4	5.5-5.9	6.0-6.4
Clay	6.7	5.2	3.8	2.3
Silty clay loam	6.9	5.3	3.7	2.1
Clay loam	7.4	5.7	4.0	2.3
Silt loam	7.0	5.5	3.9	2.4
Loam	6.2	4.8	3.3	1.8
Sandy loam	6.0	4.6	3.1	1.6
Loamy sand	5.8	4.3	2.8	1.3
Sand	5.6	4.1	2.6	1.1

Lime recommendations based on the soil test data for light colored samples (Table 14) for all textural classes analyzed, for four pH ranges and for three plowing depths are given in Table 16. The more complete data are given in Table 15 as a source of information from which this simplified table was determined for possible use in future revisions of the Lime Bulletin or "Know Your Soils."

Table 16. Recommended tons of limestone to raise the pH of plow layers of three thicknesses of light colored samples to pH 6.5.

Texture of the plow layer	Depth of plowing	Measured pH			
		4.5-4.9	5.0-5.4	5.5-5.9	6.0-6.4
Clay, silty clay loam, clay loam, and silt loam	6 2/3	7.0	5.4	3.8	2.3
	9	9.4	7.3	5.1	3.1
	12	12.6	9.7	6.8	4.1
Loam, sandy loam	6 2/3	6.1	4.7	3.2	1.7
	9	8.2	6.3	4.3	2.3
	12	11.0	8.5	5.7	3.1
Loamy sand and sand	6 2/3	5.7	4.2	2.7	1.2
	9	7.7	5.7	3.6	1.6
	12	10.3	7.6	4.9	2.2

Summary and Conclusions

In the revision of the 1962 "Know Your Soils" the original objectives were met and are summarized as follows:

1. Needs of various users were provided for by subdividing the circular into:
   a. separate topic units on general management practices, color coded for easy identification and organized so that users could obtain one section, several, or the entire circular,
   b. "pair sheets" containing management information specific to the sets of management groups contained in each, without cross references to others, make it possible to provide this information for only the soils of a given user.
2. Accuracy of the circular was increased by:
   a. review of yield estimates, fertilizer requirements, and lime requirements with corrections made where needed,
   b. replacing the erosion section with a completely new section using the universal soil loss equation approach.
3. Providing for ease of future revision by organizing the circular into separate sections and units that could each be replaced or updated as new information becomes available.
4. Comprehensive management information coverage by the circular was increased by the addition of:
   a. a section on soil sampling,

b. expanded liming information by inclusion of the bulletin "Lime for Michigan Soils" (Doll, 1964),

c. addition of profile sketches, specific minimum tillage information, and additional soil erosion control information on units of the white "pair sheets,"

d. insertion of a glossary,

e. inclusion of a list of Michigan soil series with their respective management groups.

5. Ease of use was fostered by:

a. addition of a table of contents on the page inside the front cover,[3]

b. color coding of each of the general management sections of the circular.

From this revision it is concluded that reorganization does permit revision without the necessity of replacing an entire bulletin, as demonstrated by the replacement of the lime and erosion sections. It was also concluded that periodic revision of even long established practices such as lime recommendations is necessitated by improved scientific procedures and cultural practices, such as revised soil tests, and the increase in plowing depth.

A closer tie between soil survey information and research (e.g. soil testing) is needed. There is a communication gap here as demonstrated by the suggested "Recommendations to the Michigan State Soil Testing Laboratory in regard to more effective use of soils information," Appendix D.

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[3]The table of contents was inadvertently placed at the back of "Know Your Soils" and appeared as the outside of the back cover on copies used for the testing program.

EFFECTIVENESS OF THE 1964 "KNOW YOUR SOILS"

Introduction

The final phase of the investigation evaluated the effectiveness of the 1964 "Know Your Soils" (Appendix G) in communicating soil survey and related soil management information to fourteen groups ranging from high school vocational agricultural students to agricultural specialists. A 'pretest, treatment, posttest' procedure was used to measure the increase in learning with use of "Know Your Soils." "Know Your Soils" was also compared with the Sanilac County Soil Survey Report (Schneider, 1961) and a Teaching Program written by the author (Appendix H) using this same general procedure. The study also measured the specific information most effectively communicated by each of these three sources and the kinds of information that had caused confusion as indicated by the pretest and posttest scores.

Procedure for Evaluation of the 1964 "Know Your Soils"

Groups Included in Study

The evaluation of the revised "Know Your Soils" in communicating soil survey and related soil management information was accomplished through testing groups of persons differing in education and experience. These groups included high school vocational agricultural students, farmers, college students in beginning and intermediate agricultural courses, vocational agricultural teachers, professional soil conservation planners, and professors and graduate students in the Soil Science curriculum. The details of the procedure with each group will be discussed in the Results and Discussion section with the total test scores and the changes in those scores.

The Evaluation Tests

A pretest was given to all individuals to determine previous soil knowledge. This was followed by treatment with one of three sources of information followed by a posttest to measure increased learning. In some cases the posttest was followed by working of a soil management problem and a final post-posttest.

The same 40-item evaluation form (Appendix E) was used for the pretesting, the posttesting and, where a problem was used, the post-posttesting. This evaluation form contained four major sections dealing with the following kinds of items: (a) true and false, (b) multiple choice, (c) matching, and (d) information fill-in. Each kind of item was grouped together to facilitate the answering and the grading as prescribed by Adkins (1947) as opposed to random mixing of the kinds of items.

The 40-item evaluation test was written to measure each individual's knowledge about the informational content and arrangement of the circular. It was also written to evaluate the learning of the information on soil differences, soil maps and soil classification important for the understanding of "Know Your Soils." Where other sources of information were used some of the information in "Know Your Soils" was missing. This resulted in a number of cases where no change in learning was expected.

To arrive at this evaluation form, the initial evaluation of 52-items used with the County Agricultural Agents (Appendix B) was experimentally tried on a group of experts in Soil Science in order to identify, correct, or remove test items that were not clear, that were inaccurate, or which contained more than one right answer. A section on the content and organization and a section containing definitions of key terms were removed on the basis of this experiment. They were removed partly due to the difficulty of grading them consistently and, in the case of the first, due to doubt whether it measured communication of basic information. The revised evaluation form contained four major sections.

Section I. This section contained fourteen true and false items dealing with information on soil survey maps, soil formation and classification, soil management, soil management groups, and specific subjects presented by the "Know Your Soils" circular.

Section II. This section contained seven multiple choice items, to test the understanding of soil terminology as contained in a soil type name, its mapping unit symbol, and its management unit symbol. This section, like sections III and IV, relates to specific material in "Know Your Soils" whereas section I tested more general background information in addition to "Know Your Soils." The seven items included in section II dealt with: soil texture, drainage, slope, erosion, classification and related management problems. This section was designed to measure whether individuals could identify the above mentioned soil characteristics and management problems.

Section III. Section III (8 items) was devoted entirely to the soil management group symbols and their meaning. Students were asked to match the management group symbols with each of a list of eight management group descriptions. These descriptions were written to test recognition of soil management groups ranging from those easy to identify to the most complex ones.

Section IV. Section IV (11 items) dealt with soil management practices. Three items involved plowing depth and soil texture in relation to lime requirement. Two items tested understanding of the critical soil test values of potassium and phosphorus. Six items tested understanding of soil erosion as related to the universal soil loss equation.

Item Analysis

Following use of this evaluation form an item analysis was performed on the 40 test items. The analysis was computed from the tests taken by 339 individuals that represented the full range of the groups included in this study. Each test item was evaluated for difficulty, discrimination, and total value. Item difficulty was determined as the proportion of individuals answering an item correctly. It could range from .00 to 1.00 with low numbers representing difficult items and the higher numbers representing the easier items. The items answered correctly by about one-half of the participants are considered of optimum difficulty. These values were rated from A to E according to the following table, page 65, (Table 17).

Item discrimination is a measure of item score to total score correlation. This is a correlation between individual performance on specific items as correlated to individual total test scores. The discrimination index has a range from -1.00 to +1.00 with the high positive values indicating a strong direct relationship between success on the item and success on the total test. The discrimination index was rated from A to E in accordance with Table 18.

Table 17. Item difficulty.[1]

Rating	Proportions answering correctly	Designation
A	.41 to .60	Excellent (scored 5)
B	.31 to .40 and .61 to .70	Very Good (scored 4)
C	.21 to .30 and .71 to .80	Good (scored 3)
D	.11 to .20 and .81 to .90	Fair (scored 2)
E	.00 to .10 and .91 to 1.00	Poor (scored 1)

Table 18. Item discrimination index.[2]

Rating	Item discrimination index	Designation
A	+ .71 to +1.00	Excellent (scored 5)
B	+ .51 to + .70	Very Good (scored 4)
C	+ .31 to + .50	Good (scored 3)
D	+ .11 to + .30	Fair (scored 2)
E	-1.00 to + .10	Poor (scored 1)

The item total value was an overall evaluation of each item based on the summation of the scores for item difficulty and the item discrimination index. This was done by referring these scores to Table 19. The one exception to this table is that if the item discrimination index rating is E then the item total value is also E

[1]"Explanation of the Printed Report from the Item-Analysis Program (QITAN)," University Division of Instructional Services, Pennsylvania State University. Mimeographed 5 pages.

[2]Ibid.

Table 19. Item total value[3]

Rating	Designation
A	Excellent (scored 9-10)
B	Very Good (scored 7-8)
C	Good (scored 5-6)
D	Fair (scored 3-4)
E	Poor (scored 1-2)

regardless of the item difficulty score. The results of the item analysis for the 40 test items are given in Table 20. These are used as a guide in rating of test items to help evaluate results of the test performance by the groups involved in this study.

Results and Discussion

The results of the test performances of the groups in this study were evaluated at three levels of generalization. First will come comparisons of their total test scores and changes, and then comparisons of their performances on the four sections of the test and on the individual test items. The first comparisons will also serve as an example of the general procedure as well as an introduction to the results of the study.

Comparison Among All Groups for Total Test Changes and Details of Procedure With Each Group

The names of all groups that participated in this study, their

[3]Ibid.

Table 20. Item analysis of the 40 items on "Know Your Soils" evaluation test. Based on 339 individual tests.

Item No.	Item total value	Item Difficulty rating	Item Difficulty proportion correct	Item Discrimination rating	Item Discrimination index
1	B	B	.332	C	.372
2	D	D	.847	D	.178
3	C	B	.342	D	.204
4	B	A	.434	C	.352
5	B	A	.504	D	.269
6	C	D	.879	C	.392
7	C	C	.743	C	.487
8	C	C	.720	C	.469
9	D	E	.941	C	.362
10	B	A	.587	D	.263
11	C	C	.749	D	.299
12	C	B	.661	D	.119
13	C	C	.761	C	.411
14	B	B	.614	C	.390
15	C	B	.375	D	.301
16	C	C	.227	C	.436
17	A	A	.504	B	.550
18	B	B	.676	B	.611
19	B	B	.634	B	.556
20	C	B	.637	D	.232
21	B	A	.466	C	.394
22	A	A	.599	B	.667
23	B	C	.248	B	.587
24	A	A	.537	B	.587
25	A	A	.431	B	.631
26	C	D	.112	B	.542
27	B	C	.242	A	.769
28	B	B	.345	B	.701
29	B	B	.310	B	.641
30	B	A	.519	C	.338
31	B	B	.693	C	.380
32	C	C	.776	C	.357
33	B	D	.195	A	.842
34	B	D	.198	A	.827
35	A	B	.348	A	.814
36	A	B	.348	A	.805
37	A	B	.333	A	.846
38	A	B	.310	A	.827
39	A	B	.339	A	.808
40	A	B	.310	A	.868

group designations (composed of a number and a letter), the number of persons in each, their pretest scores, posttest scores, and the percent change in their scores are given a little later in Table 21. Groups designated with the letter 'a' such as 1a, 2a, etc. through 14a are those with which the pretest, "Know Your Soils" or Sanilac Report or Teaching Program treatment, and posttest sequence was used. Groups with some of the same numbers but designated also with the letter 'b' indicate that subsequent work was done on a problem followed by a post-posttest to complete the sequence of treatments and tests used with "Know Your Soils" or the Sanilac Report.

All individuals were given the pretest to measure their initial knowledge about soils, soil maps and soil management. All groups were given brief introductions to the content and arrangement of the source materials they were to use ("Know Your Soils," the Sanilac Report, or the Teaching Program) and were then asked to read and study it.

The Soils 1 class at Michigan State University, group 4a, was lectured for one hour on topics of soil fertility, soil testing, and factors of the universal soil loss equation, then given "Know Your Soils" to study before the next class period. Groups 3a, and 7a, were given a half day training session on the content and use of "Know Your Soils" in addition to the circular. These training sessions were conducted by persons familiar with the circular and the included information.

All groups were subsequently posttested to measure their increase in knowledge as a measure of learning. All participants were requested to complete all test items, where a choice was given, even if they were uncertain of the answers. This was done in order to keep scoring of the tests consistent for everyone. Since the Teaching Program dealt only with items 6, 7, 16, 17, and 22 through 29 the remaining items were ones on which no learning should have been expected from groups using that source of information.

Groups 1b, 2b, 6b, and 14b were subsequently given a problem (Appendix I) that consisted of first identifying the soils on a specified area. The identities of these soils were recorded from the soil map provided and the soil management group to which each belonged was determined from the legend accompanying the map. Using "Know Your Soils," or the Sanilac Report each individual then determined the management practices recommended for specific problem situations concerning management of their recorded soils. This problem was designed to give individuals practice in solving soil management problems that could occur on their individual farms by using a soil survey map and the "Know Your Soils" circular. Since the Sanilac Report did not present information on items 33 to 40, these items serve as a check on the evaluation tests where no learning should have been expected. Following the problem all these individuals were given a post-posttest to determine if additional learning had resulted.

<u>Learning from "Know Your Soils" by ten groups of users as measured by total test changes</u>. The major objective of this portion of the study is to evaluate the effectiveness of the 1964 "Know Your Soils" in communicating soil survey and soil management information to various groups of potential users. This falls logically into

several subdivisions: (1) The first specific objective was to determine the percentage increase in learning for the categories of individuals having the following treatments: (a) study of the circular "Know Your Soils," or a one-half day seminar on this circular, and (b) study of "Know Your Soils" plus working a problem in the use of a soil survey in conjunction with the circular, (2) A second objective, dealt with in subsequent portions of the thesis, included determination of the kinds of information most effectively communicated by "Know Your Soils" and the kinds of information not effectively communicated. This was analyzed to determine why certain kinds of information were better communicated than other kinds. Test results from each group were analyzed to determine which kinds of information had been communicated as related to the kinds of information communicated in the other groups.

Total test comparisons with groups of users of "Know Your Soils." Groups 1, 2, and 3 did not have significant increases in their total scores as a result of exposure to "Know Your Soils," Table 21. Apparently neither the study of "Know Your Soils," by groups 1a and 2a, nor the one-half day seminar on "Know Your Soils," with group 3a, increased their knowledge significantly, at the .05 level. Group 1b increased significantly after additional practice involving the problem. It is interesting to note too that group 3a's average score actually increased slightly more than group 1b's. Apparently greater variability in this group prevented this increase from being statistically significant.

Among the 'a' groups 4 to 10, the total test percentage increases

Table 21. Summary of the mean percent scores and changes in scores for all groups on the total test (40 items).

Group No.	Groups tested	No. of persons	Scores % Pretest	Scores % Posttest	% Change
1a[1]	Vocational agriculture (KYS)	18	26.7	30.0	+ 3.3
1b[2]	Vocational agriculture (KYS)	18	26.7	33.6	+ 6.9*
2a	Vocational agriculture (KYS)	18	29.8	27.7	- 2.1
2b	Vocational agriculture (KYS)	18	29.8	33.2	+ 3.4
3a	Farmer extension soil class (KYS)	11	33.2	40.8	+ 7.6
4a	Soils 1 (KYS)	64	34.8	55.1	+20.3*
5a	Agronomy 1 (KYS)	26	37.0	44.0	+ 7.0*
6a	Soil Fertility (KYS)	18	42.5	59.2	+16.7*
6b	Soil Fertility (KYS)	18	42.5	67.7	+25.2*
7a	Vocational agriculture teachers (KYS)	8	48.1	71.3	+23.2*
8a	Edaphology (KYS)	12	63.6	76.7	+13.1*
9a[3]	Michigan State staff (KYS)	3	78.3	90.0	+11.7*
10a	Soil Conservation Service (KYS)	12	73.8	81.9	+ 8.1*
11a	Agronomy 1 (Sanilac Report)	24	37.4	50.7	+13.3*
12a	Agronomy 1 (Teaching Program)	17	44.0	57.2	+13.2*
13a	Agronomy 1 (Teaching Program)	22	34.2	51.8	+17.6*
14a	Soil Fertility (Sanilac Report)	15	39.3	42.7	+ 3.4
14b	Soil Fertility (Sanilac Report)	15	39.3	47.5	+ 8.2*

[1]All group numbers containing (a) indicate pretest to posttest.

[2]All group numbers containing (b) indicate pretest to post-post-test.

[3]Thirteen Michigan State staff took the pretest to aid in evaluating the test items but only three took the posttest, therefore the data is based on the three persons.

*Significant at .05 level.

ranged from 7% to 23% with the "Know Your Soils" treatment and all of the increases were significant. Group 7a (vocational agriculture teachers), who were given a seminar on "Know Your Soils," increased their score 23.2%, the largest increase for any group. Group 6b (Soil Fertility students) increased their score 8.5% over that of 6a after working the problem. All groups that worked the problem (1b, 2b, and 6b) showed an increase in their score. Increases varied from 3.4% (the only one not significant) to 8.5% following use of the problem compared to the posttest scores.

<u>Learning from "Know Your Soils" compared to learning from the Sanilac Report</u>. A comparison of the effectiveness of "Know Your Soils" with the Sanilac Report on the communicating of soil management information was made using two college classes in agriculture at The Pennsylvania State University. The Agronomy 1 class consisted of four laboratory sections. One, group 5a used "Know Your Soils," another, group 11a, used the Sanilac Report and the two remaining sections, groups 12 and 13, used the Teaching Program. The Soil Fertility class was randomly split into two groups. One, group 6a, used "Know Your Soils" and the other, group 14a, used the Sanilac Report. The Soil Fertility students, reported as groups 6b and 14b, were given a management problem following the posttest and subsequently post-posttested to determine any further increase in learning. Use of the problem revealed some difficulties and differences in communicating 'lime requirement information' that was studied further and reported later in this thesis.

<u>Total test comparisons with users of "Know Your Soils" compared to users of the Sanilac Report</u>. The 6a group of Soil Fertility

students using "Know Your Soils" had a 13% greater increase from the pretest to the posttest than the 14a group of Soil Fertility students, Table 21, using the Sanilac Report. The 6a group increase, over their pretest score, was statistically significant at the .05 level while the increase of the 14a group was not. In both cases the addition of a problem to the treatment also gave a significant increase over the pretest scores. But, the increase in score following the problem was 8.5% for the group using "Know Your Soils" and only 3.8% for the group using the Sanilac Report.

The Agronomy 1 class (5a) using "Know Your Soils" had a smaller increase in score than the Agronomy 1 class (11a) using assigned portions of the Sanilac Report. However, both had significant increases at the .05 level over their pretest scores.

<u>Learning from "Know Your Soils" and the Sanilac Report relative to the Teaching Program</u>. Finally, a three-way comparison was made among the 1964 "Know Your Soils," the Sanilac County Soil Survey Report, and the Teaching Program that gives an intensive presentation of the Soil Management Group classification.

<u>Total test comparisons with users of "Know Your Soils," and users of the Sanilac Report, compared to users of the Teaching Program</u>. The increases in scores of the Agronomy 1 students that used the Teaching Program, groups 12a and 13a, were equal to or greater than the increases of those using the assigned portions of the Sanilac Report, group 11a, and those using "Know Your Soils, group 5a, Table 21. All these groups increased their scores significantly on the posttests compared to the pretests. Since the Sanilac Report and the Teaching Program did not cover all the items

in the test evaluation these greater total scores are very striking. All these results will be examined in greater detail later in this chapter.

Summary of total test scores. In summary, "Know Your Soils," judged by the mean test scores, Table 21, was least effective in communicating soil management information with groups with the least initial knowledge about the subject as indicated by pretest scores below 30%. It was most effective with groups having greater initial understanding as indicated by pretest scores of 40% to 65%. It was somewhat less effective, judged by increases in total scores, with groups with the greatest initial understanding as indicated by pretest scores over 70%. However, the increases were statistically significant for all groups with initial scores of over 34%

"Know Your Soils" was more effective than the Sanilac Report with the Soil Fertility class but less effective than the Sanilac Report with the Agronomy 1 class. For all groups that also worked a problem there was an increase in learning.

Those using the Teaching Program had equal or greater increases in scores than those using the Sanilac Report or "Know Your Soils." The importance of these general observations will become more apparent by more detailed comparisons of the test scores by sections of the test and by examination of results on the individual test items in the following comparisons.

Comparisons Among All Groups for Changes in Test Scores on Each Test Section and Individual Items

1. Evaluation of "Know Your Soils" Treatment for Groups 1 to 10 for Each Test Section I to IV

Section I. The effect of the "Know Your Soils" treatment on the test scores for the 14 true and false items are given in Table 22. Groups 6a, 8a, and 10a had significant test score increases as a result of using the circular. These three groups included advanced college students and professional conservation personnel.

The 12% increase of the Soil Fertility students in group 6a apparently indicates that a group of this caliber is able to absorb a broad spectrum of information covered by section I of the test evaluation from the circular. The increase probably also reflects student interest, associated with the fact that these students were dealing with soil management information in their course work at the time of exposure to "Know Your Soils." Increases were most noticeable for items 4, 6, 7, 10, and 13, (Appendix A, Table H, and Appendix E) which dealt with parent materials of the soils, soil management group information, response of oats to manganese where needed, and information about blinding of tile in sandy materials. Increases were recorded for ten of the fourteen items and decreases on only two, items 1 and 11. This distribution seems to indicate that these students got a broad grasp of the information covered in "Know Your Soils" rather than being limited to improvement in any specific area of information.

The 7% increase by the Edaphology class, group 8a, was the

Table 22. Summary of the mean percent scores and changes in scores for all groups on test section I (14 true and false items on overall information).

Group No.	Groups tested	No. of persons	Scores % Pretest	Scores % Posttest	% Change
1a[1]	Vocational agriculture (KYS)	18	52.3	54.3	+ 2.0
1b[2]	Vocational agriculture (KYS)	18	52.3	57.1	+ 4.8
2a	Vocational agriculture (KYS)	18	58.7	49.6	- 9.1
2b	Vocational agriculture (KYS)	18	58.7	58.3	- .4
3a	Farmer extension soil class (KYS)	11	58.4	61.3	+ 2.9
4a	Soils 1 (KYS)	64	59.0	63.1	+ 4.1
5a	Agronomy 1 (KYS)	26	61.5	62.6	+ 1.1
6a	Soil Fertility (KYS)	18	62.3	74.5	+12.2*
6b	Soil Fertility (KYS)	18	62.3	74.5	+12.2*
7a	Vocational agriculture teachers (KYS)	8	68.3	68.8	+ .5
8a	Edaphology (KYS)	12	76.2	83.3	+ 7.1*
9a[3]	Michigan State staff (KYS)	3	95.2	95.2	0.0
10a	Soil Conservation Service (KYS)	12	76.8	82.7	+ 5.9*
11a	Agronomy 1 (Sanilac Report)	24	60.7	61.6	+ .9
12a	Agronomy 1 (Teaching Program)	17	63.4	60.0	- 3.4
13a	Agronomy 1 (Teaching Program)	22	52.9	55.8	+ 2.9
14a	Soil Fertility (Sanilac Report)	15	61.9	65.2	+ 3.3
14b	Soil Fertility (Sanilac Report)	15	61.9	67.6	+ 5.7

[1]All group numbers containing (a) indicate pretest to posttest.

[2]All group numbers containing (b) indicate pretest to post-posttest.

[3]Thirteen Michigan State staff took the pretest to aid in evaluating the test items but only three took the posttest, therefore the data is based on the three persons.

*Significant at .05 level.

result of increases in seven of the fourteen test items and decreases on only two items, Appendix A, Table K. These reflect again a broad increase in knowledge. The significant increase in scores by Soil Conservation Service personnel in group 10a is also accomplished by relatively uniform increases among the 14 test items, with 9 items increasing and only 1 decreasing, Appendix A, Table M. It should be noted that both group 8a and 10a had pretest scores greater than 76%, Table 22. This makes increases rather difficult since information learned at high levels of achievement is more difficult than those at initially lower levels.

In summary it would seem that groups having significant increases in scores on section I were those who had a direct interest in the overall subject of soil management with sufficient background to permit them to identify and learn information that they had not previously been familiar with.

The additional treatment of a problem with groups 1b, 2b, and 6b gave no significant increases in learning, Table 22. Examination of the individual questions for these groups, Tables B, D, and I, Appendix A, showed consistent improvement on items 2, 6, and 11, all dealing with items used in the problem. Group 6b showed no net change between posttest and the post-posttest. Despite no net increase for this test section, it should be noted that for item 7 there was a 33% increase between posttest and post-posttest.

Section II. A summary of test scores for the 7 items (15-21) of section II are given in Table 23. The small number of items made it difficult to obtain statistically significant changes resulting from the "Know Your Soils" treatment. The 12% increase for vocational

Table 23. Summary of the mean percent scores and changes in scores for all groups on test section II (7 items on soil classification and its symbols).

Group No.	Groups tested	No. of persons	Scores % Pretest	Scores % Posttest	% Change
1a[1]	Vocational agriculture (KYS)	18	27.0	39.7	+12.7
1b[2]	Vocational agriculture (KYS)	18	27.0	32.6	+ 5.6
2a	Vocational agriculture (KYS)	18	30.1	19.8	-10.3
2b	Vocational agriculture (KYS)	18	30.1	25.4	- 4.7
3a	Farmer extension soil class (KYS)	11	35.0	29.7	- 5.3
4a	Soils 1 (KYS)	64	41.1	46.1	+ 5.0
5a	Agronomy 1 (KYS)	26	41.1	50.6	+ 9.5
6a	Soil Fertility (KYS)	18	48.4	61.8	+13.4
6b	Soil Fertility (KYS)	18	48.4	69.0	+20.6
7a	Vocational agriculture teachers (KYS)	8	58.7	66.1	+ 7.4
8a	Edaphology (KYS)	12	72.5	75.0	+ 2.5
9a[3]	Michigan State staff (KYS)	3	80.9	85.7	+ 4.8
10a	Soil Conservation Service (KYS)	12	69.0	71.4	+ 2.4
11a	Agronomy 1 (Sanilac Report)	24	38.7	48.8	+10.1
12a	Agronomy 1 (Teaching Program)	17	44.6	49.6	+ 5.0
13a	Agronomy 1 (Teaching Program)	22	45.4	53.8	+ 8.4
14a	Soil Fertility (Sanilac Report)	15	43.8	60.0	+16.2
14b	Soil Fertility (Sanilac Report)	15	43.8	62.8	+19.0*

[1]All group numbers containing (a) indicate pretest to posttest.

[2]All group numbers containing (b) indicate pretest to post-post-test.

[3]Thirteen Michigan State staff took the pretest to aid in evaluating the test items but only three took the posttest, therefore the data is based on the three persons.

*Significant at .05 level.

agriculture students in group 1a compared to the 10% decrease for vocational agriculture students in group 2a would suggest that factors other than the "Know Your Soils" treatment had considerable effect on student test scores. This might be attributed to interest or lack of interest generated by the instructors of the two classes.

It is noteworthy that group 1b increased 44% on item 18, dealing with soil slope classes, between the pretest and the post-posttest, Tables A and B, Appendix E. Most of this increase resulted from the use of "Know Your Soils" without the working of a problem. This increase in knowledge about soil slope as determined from the soil management unit symbol and the soil mapping unit symbol is considered significant as this item was rated very good in both item difficulty and item discrimination during the item analysis for 339 of the participants.

It is also interesting to note that item 15, dealing with texture of the surface soil, showed decreases in test scores for 7 of the 10 groups and no change in test scores for the other 3 groups, Tables A through M, Appendix A. This is interpreted as evidence that individuals were confused on the texture of the surface soil, as given in the soil type name, perhaps as a result of using "Know Your Soils" which stresses average texture of the profile indicated by the soil management group symbol. Clearly, more stress on differentiating these two is needed in the circular.

In summary, section II had no statistically significant increase in test scores for groups 1 to 10, although group 1a had a 12% increase, 6a had a 13% increase and 6b had a 20% increase in score. The lack of significance was attributed largely to the small number of items. All these groups had an increase in score between pretest and post-posttest on items 16, 17, and 18 dealing with profile texture, drainage, and slope of soils, respectively. Seven of the ten groups decreased, two remained unchanged, and only one, group 1, increased in score on item 15. This is interpreted as due to confusion between the texture of soil profiles as given by the soil management group and the soil surface texture given in the soil type name.

Section III. Test scores for section III, items 22-29, as affected by the "Know Your Soils" treatment are given in Table 24, groups 1 to 10. Five of the 'a' groups had significant increases in score as a result of the "Know Your Soils" treatment. The non-significant changes for the vocational agriculture students (groups 1a and 2a) and the farmers in the extension soils class (group 3a) following the "Know Your Soils" treatment agrees with the overall test scores for these groups, Table 21. However, the problem increased learning appreciably in the vocational agriculture groups, 1b and 2b, Table 24. Indeed the vocational agriculture students in group 1b showed a 13.9% increase that was statistically significant at the .05 level. The farmers in the extension soil class, group 3a, also increased their scores nearly 19%. Groups 4 to 7 including college of agriculture students and vocational agriculture teachers had large significant increases in their scores ranging from 18 to 36%. The pretest scores of these groups ranged from 11% to 26% indicating that the individuals had little knowledge of soil management group characteristics prior to studying "Know Your Soils." These relatively low pretest scores and large increases in scores indicate that for these groups of persons the "Know Your Soils" circular was highly effective in

Table 24. Summary of the mean percent scores and changes in scores for all groups on test section III (8 items on management group symbols).

Group No.	Groups tested	No. of persons	Scores % Pretest	Posttest	% Change
1a[1]	Vocational agriculture (KYS)	18	4.9	3.5	- 1.4
1b[2]	Vocational agriculture (KYS)	18	4.9	18.8	+13.9*
2a	Vocational agriculture (KYS)	18	4.9	5.5	+ .6
2b	Vocational agriculture (KYS)	18	4.9	11.1	+ 6.2
3a	Farmer extension soil class (KYS)	11	13.6	32.3	+18.7
4a	Soils 1 (KYS)	64	11.0	37.8	+26.8*
5a	Agronomy 1 (KYS)	26	10.1	33.1	+23.0*
6a	Soil Fertility (KYS)	18	14.6	33.4	+18.8*
6b	Soil Fertility (KYS)	18	14.6	47.3	+32.7*
7a	Vocational agriculture teachers (KYS)	8	26.4	62.5	+36.1*
8a	Edaphology (KYS)	12	63.5	64.6	+ 1.1
9a[3]	Michigan State staff (KYS)	3	87.5	91.6	+ 4.1
10a	Soil Conservation Service (KYS)	12	74.0	83.4	+ 9.4*
11a	Agronomy 1 (Sanilac Report)	24	11.5	28.1	+16.6
12a	Agronomy 1 (Teaching Program)	17	10.3	65.5	+55.2*
13a	Agronomy 1 (Teaching Program)	22	9.1	50.0	+40.9*
14a	Soil Fertility (Sanilac Report)	15	11.6	20.0	+ 8.4
14b	Soil Fertility (Sanilac Report)	15	11.6	37.5	+25.9*

[1]All group numbers containing (a) indicate pretest to posttest.

[2]All group numbers containing (b) indicate pretest to post-post-test.

[3]Thirteen Michigan State staff took the pretest to aid in evaluating the test items but only three took the posttest, therefore the data is based on the three persons.

*Significant at .05 level.

communicating soil management group information. Group 10a, Soil Conservation Service personnel, had a significant 9% increase from a 74% pretest score indicating that although they knew considerable about soil management groups prior to studying "Know Your Soils" they increased their knowledge about the subject a significant amount. Group 8a, the Edaphology class, had a relatively high 63% pretest score but were unable to increase this significantly through use of "Know Your Soils."

Items 22, 25, and 28 had the largest increase among all groups, Tables A through M, Appendix A. This would seem to indicate that persons learned the fundamental concepts of texture and drainage illustrated by these three relatively basic soil management groups. Item 26 had the smallest increase and the largest proportion incorrect on both pretest and posttest. This is to be expected as the item dealt not only with drainage but had an 11 inch depth of sand which was not sufficiently deep to group the soil as a sand over rock, 4/Rc, as most people had indicated.

Use of a problem on groups 1b, 2b, and 6b, increased their scores in each case, Table 24. In the case of 1b, the 13.9% increase over pretest was sufficient to make this a statistically significant change over the pretest score. The 6.2% increase of group 2b was not sufficient to give statistical significance. The significant 32.7% increase in group 6b from pretest to post-posttest was 14% over the "Know Your Soils" treatment alone. The problem treatment between posttest and post-posttest gave a greater than 30% increase on item 22 for the mean of the scores of groups 1b, 2b, and 6b, Tables B, D, and I, Appendix A.

In summary, the effect of the "Know Your Soils" treatment on items in section III of the test was greatest for those groups that included college students and vocational agriculture teachers who had relatively low pretest scores. A significant increase was also obtained with the Soil Conservation Service personnel despite their high, 74%, pretest score. The problem treatment resulted in a nonsignificant 6.2% increase for group 2b, a significant 13.9% increase for group 1b, and a significant increase of 32.7% for group 6b compared to their pretest scores. The increases over the posttest scores were 6% to 14% in all cases. Test items 22, 25, and 28 were most affected by the "Know Your Soils" treatment. A significant increase in scores occurred in item 22 as a result of the problem given prior to the post-posttesting.

Section IV. The effect of the "Know Your Soils" treatment on the test scores in section IV, items 30 to 40, is given in Table 25. Most groups using "Know Your Soils" had significant increases ranging from 10.1% to 57.9%. Only the vocational agriculture group 1a with a 2.5% increase and the Agronomy 1 class group 5a with a 1.1% increase did not have significant increases following the "Know Your Soils" treatment. The 13% increase of group 10a was not significant, perhaps because of their initial high score of 73.4% and the relatively small number of test items, 30, 33, 34, and 36 on which their scores increased appreciably, Table M in Appendix A. The vocational agriculture students of group 2a apparently learned nothing on items 33 and 34 dealing with the critical soil test values for phosphorus and potassium, Tables C, Appendix A. Their increase was evenly distributed among the balance of the items. In contrast with this the farmers of

Table 25. Summary of the mean percent scores and changes in scores for all groups on test section IV-A+B+C (11 items on soil management: lime, fertility, erosion).

Group No.	Groups tested	No. of persons	Scores % Pretest	Scores % Posttest	% Change
1a[1]	Vocational agriculture (KYS)	18	9.6	12.1	+ 2.5
1b[2]	Vocational agriculture (KYS)	18	9.6	15.2	+ 5.6
2a	Vocational agriculture (KYS)	18	10.6	20.7	+10.1*
2b	Vocational agriculture (KYS)	18	10.6	22.1	+11.5*
3a	Farmer extension soil class (KYS)	11	14.1	30.6	+16.5*
4a	Soils 1 (KYS)	64	17.2	62.9	+45.7*
5a	Agronomy 1 (KYS)	26	22.7	23.8	+ 1.1
6a	Soil Fertility (KYS)	18	33.8	56.5	+22.7*
6b	Soil Fertility (KYS)	18	33.8	72.7	+38.9*
7a	Vocational agriculture teachers (KYS)	8	27.3	85.2	+57.9*
8a	Edaphology	12	41.6	78.0	+36.4*
9a[3]	Michigan State staff (KYS)	3	48.5	84.8	+36.3*
10a	Soil Conservation Service (KYS)	12	73.4	86.4	+13.0
11a	Agronomy 1 (Sanilac Report)	24	72.3	64.0	- 8.3
12a	Agronomy 1 (Teaching Program)	17	42.4	45.8	+ 3.4
13a	Agronomy 1 (Teaching Program)	22	39.0	40.0	+ 1.0
14a	Soil Fertility (Sanilac Report)	15	27.9	19.4	- 8.5*
14b	Soil Fertility (Sanilac Report)	15	27.9	19.4	- 8.5*

[1]All group numbers containing (a) indicate pretest to posttest.

[2]All group numbers containing (b) indicate pretest to post-posttest.

[3]Thirteen Michigan State staff took the pretest to aid in evaluating the test items but only three took the posttest, therefore the data is based on the three persons.

*Significant at .05 level.

group 3a did benefit from "Know Your Soils" in respect to items 33 and 34, Table E, Appendix A. This perhaps should be expected since this group was involved in a soil testing program for their soils with the County Agent and were therefore directly concerned with this type of information.

The Soils 1 class, group 4a, had information from "Know Your Soils" on soil fertility and soil testing and on soil erosion control as related to the universal soil loss equation presented to them in a lecture. This becomes evident in the increase in scores on items 33 and 34 dealing with soil test information and on items 35 to 40 dealing with universal soil loss equation, Table F, Appendix A. Increases on these items ranged from 36% to 78% and illustrate the impact of information being presented in lecture form on specific subjects with a circular such as "Know Your Soils." The significant increase in learning by the Soil Fertility class, group 6a, is attributed to items 33 to 40 which includes soil test values and soil erosion control, Table H, Appendix A. The initially high pretest scores on liming, items 30, 31, 32, made it difficult for those items to increase between pretest and posttest. Apparently those students were familiar with the information on liming prior to exposure to "Know Your Soils." The 58% increase in score for the vocational agriculture teachers, group 7a (Table 25) was obtained largely from items 33 and 34 and items 35 to 40, Table J, Appendix A. This indicates that they benefited greatly from the exposure to the "Know Your Soils" training seminar on the topics of soil fertility and soil erosion (as related to the universal soil loss equation). The 36% increase of Edaphology students, Table 25, is also attributable primarily to the areas of soil testing items 33, 34, and the universal soil loss equation items 35 to 40, Table K, Appendix A. Their high pretest scores on items 30 to 32 prevented large increases on these items. Soil Conservation Service personnel, group 10a, had little opportunity to benefit in the area of soil erosion control as they had high initial scores, Table M, Appendix A. They did, on the other hand, increase their scores appreciably in the area of soil testing.

Working of a problem by the vocational agriculture students, groups 1b and 2b, apparently had little beneficial effect on their scores, Table 25. The items most affected were 33 and 34 dealing with critical soil test values, Tables B and D in Appendix A. The college Soil Fertility students, group 6b, benefited most from working a problem on items 33 and 34 on critical soil test values, but they also benefited to a lesser extent on items 35 to 40 dealing with the universal soil loss equation information, Table I, Appendix A.

A summary of test section IV results for groups 1 to 10 indicates that the scores of groups 1a, 5a, and 10a did not show significant increases in this section as a result of exposure to "Know Your Soils, Table 25. Groups 2a, 3a, 4a, 6a, 7a, and 8a did have significant increases as a result of the "Know Your Soils" treatment. These increases in scores ranged from 10% to 57%. The items contributing the greatest amount to these significant increases were ones that were: (a) stressed to a group in a lecture or seminar dealing with the "Know Your Soils" circular, (b) subjects of direct interest to groups such as farmers involved in a soil testing program or (c) information closely related to subject matter that the particular group had been dealing with in class studies, or directly related to the group's type of work.

2. Comparison of "Know Your Soils" and Sanilac County Soil Survey Report

The relative effectiveness of the "Know Your Soils" circular compared to the Sanilac County Soil Survey Report in communicating soil management information was measured using two groups of students. The comparison was made between one laboratory section of an Agronomy 1 class using "Know Your Soils," group 5a, and a second laboratory section of this class using the Sanilac Report, group 11a. Comparison was also made between one-half of a Soil Fertility class consisting of 18 randomly selected students using "Know Your Soils, group 6a, compared with the other half of the Soil Fertility class, group 14a, using the Sanilac Report. All groups received a pretest, a treatment in the form of the respective sources of information, and a posttest to measure learning. Subsequent to posttesting the Soil Fertility class, groups 6b and 14b, were given problems involving use of their respective sources of information to determine answers to soil management problems. This was followed by a post-posttest to measure any change caused by the problem treatment.

Section I. Section I of the evaluation test showed no significant increase in learning for either the Agronomy 1 section using "Know Your Soils," group 5a, or the Agronomy 1 section using the Sanilac Report, group 11a, Table 22. Soil Fertility students, group 6a, using "Know Your Soils" showed a 12% increase in score between pretest and posttest. This was significant at the .05 level. Soil Fertility students using the Sanilac Report, group 14a, showed a 3.3% increase in score which was not significant. The "Know Your Soils" treatment gave a larger increase in scores than the Sanilac treatment on a basis of having slightly higher increases on 8 items and slightly smaller increases on only four of the items, Tables H and Q, Appendix A. The subsequent problem treatment for both groups, 6b and 14b, caused no significant increases in scores, Table 22. The 6b group's score using "Know Your Soils," however, remained significantly better than the pretest score at 12.2%. The problem treatment with group 14b, the Soil Fertility students using the Sanilac Report, accompanied an increase of 2.4% from its posttest score although this still was not a significant increase over their pretest score. Items increasing most for both groups from the problem treatment were items 6 and 7, dealing with the properties of soil management groups, Tables I and R in Appendix A. This increase seems reasonable as students were required to use soil management groups and understand their characteristics in working the problem.

Section II. A comparison of the Agronomy 1 students using "Know Your Soils, group 5a, and the Agronomy 1 students using the Sanilac Report, group 11a, on subjects covered in test section II, dealing with soil classification and its symbols, Table 23, shows an average increase for the "Know Your Soils" group of 9.5% and for the Sanilac Report group of 10.1%. Neither of these increases was significant at the .05 level. Despite the non-significant total increases by both groups on this section, examination of the individual items indicates that apparently both groups improved more than average on items 16 and 17 dealing with interpretation of the soil management groups symbols, Tables G and N, Appendix A. Also, group 5a, using "Know Your Soils" increased 15% in item 21, dealing with a management hazard, and group 11a, using the Sanilac Report, increased 25% on item 18 which involves understanding the slope class included in both mapping unit and management unit symbols. Both groups decreased in their scores on item 19 dealing with erosion classes. Group 5a showed a 27% decrease on item 15 dealing with surface soil texture.

Soil Fertility students using "Know Your Soils," group 6a, and Soil Fertility students using the Sanilac Report, group 14a, had increases in their test scores on section II of 13.4% and 16.2% respectively, Table 23. After working a problem both groups registered further increases to 20.6% and 19.0%, respectively. These relatively large increases were not significant because of the small number of items on which the test was based, except for the 19.0% for group 14b. Items 17, 18, 19, and 21 showed the most notable increases for both groups in the initial treatments and 16 showed notable further increases after working a problem, Tables H and Q, Appendix A. The respective increases of items for the two groups seem reasonable in light of the fact that the management groups and soil properties are stressed in both presentations. The scores of both groups decreased on item 15 dealing with surface texture. Apparently, there has been some confusion of surface soil textures with the average textures of the profiles in both cases. The profile textures are stressed in the management groups but the surface texture, given in the soil type name, is important in lime need estimations.

Section III. A comparison between "Know Your Soils" and the Sanilac County Soil Survey Report as sources of information on test items in section III (on management group symbols) is given in Table 24. The Agronomy 1 group using "Know Your Soils" 5a, and the Sanilac Report, 11a, increased their scores as a result of those treatments 23% and 17%, respectively. The former was statistically significant at the .05 level. The "Know Your Soils" treatment on group 5a resulted in marked increases on items 22, 24, 25, and 28, Table G, Appendix A. These items involved the relatively basic information on soil management group symbols. The items benefiting most from the Sanilac Report treatment on group 11a were items 23, 25, and 26 which increased at least 33% each, Table N, Appendix A. Increased scores on these three items is somewhat surprising since none of these management groups are given directly in the table of management groups supplied in the Sanilac Report. Explanation of increases on these items suggests that students were able to use knowledge about the basic connotative symbols of soil management groups and their arrangement to deduce the correct management unit symbols for the descriptions given in the items of section III. The numerical symbol for clay was not given in the Sanilac Report. This conclusion is further substantiated by the fact that no students got items 23 and 26 correct in the pretest and only one student got item 25 correct in the pretest indicating that students with no knowledge about the soil management group system of nomenclature are not able to consistently guess correct answers in the form in which this section of the test was presented.

Soil Fertility students using "Know Your Soils," group 6a, had an 18% increase in section III while those using the Sanilac Report, group 14a, had only an 8% increase which was not significant, Table 24. The increase following the problem with Soil Fertility students using "Know Your Soils," group 6b, was nearly 14% over the posttest score and for those using the Sanilac Report, group 14b, the increase was

17% over the posttest score. Thus, both groups benefited appreciably by working the problem.

The Soil Fertility students using "Know Your Soils" improved most notably on items 25 and 28 which deal with the basic concepts of the soil management group system of nomenclature and indicate that these are readily learned by students who have not been exposed to the management group system previously, Tables H, Appendix A. The group of Soil Fertility students using the Sanilac Report did not increase notably on any of the test items although they did increase somewhat on 5 of the 8 items, Table Q, Appendix A. The problem treatments resulted in further increases on items 25, and 28 for the "Know Your Soils" group and in appreciable increases on items 22 and 27 all of which deal with knowledge about the basic characteristics of the management groups, Table I, in Appendix A. The Soil Fertility group of students after treatment with a problem increased most conspiciously on items 22 and 25, Table R in Appendix A. This indicates that they, through exposure to a problem in the use of soil management groups, learned most about the basic soil management group terminology.

Section IV. A comparison between "Know Your Soils" and the Sanilac Report as effective information sources on test items in section IV is given in Table 25. The Agronomy 1 students using the "Know Your Soils" circular, group 5a, and those using the Sanilac Report, group 11a, showed no significant changes in their scores. However, the latter was actually a decrease of 8.3%. Both these groups had small negative scores on section IV-A, items 30 to 32 dealing with relative lime needs based on relative surface textures and thicknesses of plow layers, Tables G and N, Appendix A. Both groups had relatively high scores to begin with and apparently learned nothing from either "Know Your Soils" or the Sanilac Report. The Sanilac Report gave no information relative to sections IV-B or IV-C so the scores cited apply only to IV-A, items 30 to 32. The "Know Your Soils" gave no significant increases with Agronomy 1 students on sections IV-B or IV-C.

The Soil Fertility group, 6a, had a 22% increase from use of "Know Your Soils" on section IV, Table 25. This was further increased to nearly 39% after a problem treatment was given, group 6b. The Soil Fertility group, 14a, using the Sanilac Report had a small but apparently significant decrease of 8.5% after use of the report. This figure remained unchanged following the problem treatment. The Sanilac Report gave no information on section IV-B or IV-C and scores on those sections began and remained near zero for group 14 as should be expected.

The increase in learning for group 6a, using "Know Your Soils," was attributable to items 33 and 34, section IV-B, dealing with the critical soil test values, and items 35 to 40, section IV-C, dealing with the universal soil loss equation, Table H, Appendix A. Scores on both these subjects were low on the pretest. Further increases in learning occurred in both of these areas after the problem treatment, Table I, Appendix A, when scores of group 6b had increased to 66% and 50% respectively.

It is important to note that scores on items in sections IV-B and IV-C illustrate that material not covered by a source of information, such as the Sanilac Report in these tests, may cause a net decrease in score, possibly due to fatigue of the participants, rather than a net increase that might be possible due to random guessing of answers.

This should give added confidence in the positive scores that were obtained. The item analysis, Table 20, showed that items 30 to 32 gave good discrimination and items 33 to 40 were of excellent value. The apparent suitability of these items to test learning also lends support to the above observations of lack of response of the groups not receiving information on these items and the positive response of groups that had received information on these items.

Use of "Know Your Soils" and Sanilac Report in Solving Problems. Answers on the problem sheets of the Soil Fertility students, group 6b, using "Know Your Soils" and those using the Sanilac Report, group 14b, as sources of information to work the problem were compared. The outstanding feature noted in this comparison was that only 17% of the students using "Know Your Soils" as a source of information got correct answers for the lime requirement question (Appendix I, item c, 2), but 80% of those using the Sanilac Report got correct answers. Sixty percent of these students commented on the difficulty of locating the lime information in the Sanilac Report and 13% indicated their need for a more complete index to facilitate location of specific items of information in the report. The problem of using information from these two different sources to determine lime requirements was therefore investigated more extensively.

Review of the two sources of information and analysis of the lime requirement values given as incorrect answers indicated that the relatively simple lime table used in the Sanilac Report was easier to use than the several steps necessary in the 1964 "Know Your Soils" to determine the lime requirement of a soil. It was hypothesized, and suggested by some of the students, that lime requirement tables in which values could be determined directly without the need of several steps would increase the efficiency and accuracy of communicating this kind of information. This was the mode of presentation in the Sanilac Report but the variation in depths of plowing also needs to be introduced in addition to pH and surface texture. Clearly separated pH ranges might also facilitate use. In addition, different recommendations are also made now for alfalfa compared to other crops.

Comparison of two sources of liming information. To test the accuracy of communicating lime needs information, lime requirement tables were constructed that included the soil pH, texture of the plow layer, and plowing depth for use with alfalfa and with other field crops. These tables were presented along with narrative material that was equivalent to that given in the Michigan Lime Bulletin (Doll, 1964) on a single page in each case. The two different sources of information were reproduced, Citations 1 and 2, and used with students of two Agronomy 1 laboratory sections along with the following problem:

> For a well drained loamy sand soil, determine its lime requirement per acre for seeding alfalfa if its surface pH is 5.5 and the plow layer is 9 inches thick.

Laboratory Section A was given the reproduction of lime determination information including tables and graphs from the Michigan Lime Bulletin, Citation 1. Laboratory Section B was given the revised lime information sheet, Citation 2. Only 23% of the 13 students in Laboratory Section A got correct answers. This corresponds closely to the 17% correct for the Soil Fertility students, group 6b, that initially did the lime problem using the Michigan Lime Bulletin in "Know Your Soils." In contrast with this, 100% of the 11 students in

Measuring Lime Needs

Measurements of soil pH, as made in the county soil testing laboratories, are used to determine if a soil should be limed. Lime needs can then be estimated from Table 3 on the basis of soil pH and soil texture.

In the state soil-testing laboratory at Michigan State University, a lime-requirement test is made in which both active hydrogen, or pH, and exchangeable hydrogen and aluminum, or potential acidity, are measured. This gives a more precise determination of lime requirement than the estimates made from soil pH and soil texture. However, satisfactory results are usually obtained from Table 3; any errors in lime recommendations usually result in underliming rather than overliming, so that additional lime may be applied after the soil is retested.

Lime recommendations made in either the state or county laboratories are in terms of the amount of ground limestone, with a *neutralizing value of 90%*, required to raise the pH of a *6⅔-inch plow layer* to *pH 6.5.*

From fields on which alfalfa is to be grown, a pH value between 6.8 and 7.0 is desirable; consequently, the recommendation from Table 3 should be *increased approximately one ton per acre when alfalfa is to be grown.* For some crops where lower pH values may be desirable, the recommendations can be decreased accordingly.

Limestones sold in Michigan usually range from 80 to 103% calcium carbonate equivalent, so the lime recommendations given in Table 3 from the central soil-testing laboratory should be adjusted for liming materials with neutralizing values different from 90. Figure 2 can be used for this purpose.

Liming rates given in Table 3 refer to a plow layer of 6⅔ inches. With the advent of larger tractors and plows, many farmers regularly plow to a depth of 10 to 12 inches. Consequently, heavier lime applications will be necessary to reach the desired pH levels. Recommendations derived from Table 3 (and Figure 2) can readily be converted for deeper plowing depths by using Figure 3. Examples of liming recommendations developed by using Table 3 and Figures 2 and 3 are given in Table 4.

Magnesium Needs in Michigan

Magnesium deficiency may occur in acid soils that have a sandy loam, loamy sand, or sand plow layer with a subsoil as coarse or coarser in texture than the plow layer, and in similar soils limed with calcic limestone or marl. Responsive crops are cauliflower, muskmelons, potatoes, peas, oats, wheat and rye. Dolomitic limestone should be applied to acid sandy soils which have less than 75 pounds of exchangeable magnesium per acre, as measured in the state laboratory.

Table 3. Tons of limestone to raise the pH of a 6-2 3-inch plow layer of different soils to pH 6.5.

Texture of plow layer	Soil Management Group	pH Range 4.5 to 4.9	5.0 to 5.4	5.5 to 5.9	6.0 to 6.4
		Tons of lime recommended*			
Clay and silty clay	1	6	5	4	2½
Clay loams or loams	2	5	4	3	2
Sandy loams	3	4	3	2½	1½**
Loamy sands	4	3	2½	2	1**
Sands	5	2½	2	1½**	½**

*Lime recommendations based on a liming material having 25 per cent passing through a 100-mesh sieve and having a neutralizing value of 90 per cent.
**It is preferable to recommend 2 tons per acre so as to obtain uniform application and to justify the expense of application.

Table 4. — Examples of lime recommendations developed using Table 3 and Figures 2 and 3.

pH	Texture	Alfalfa to be grown*	Neutralizing Value of Lime	Plow Depth (inches) 6⅔	9	12
				Tons of Lime		
5.5	Sandy loam	Yes*	90	3½	4½	6
5.5	Sandy loam	No	90	2½	3½	4½
5.6	Loamy sand	Yes*	105	2½	3½	4½
6.2	Loam	No	70	2½	3½	4½
4.8	Sandy loam	Yes*	80	5½**	7½**	10**
5.7	Clay loam	Yes*	103	3½	4½	6**

*When alfalfa is to be grown, the rate of application should be increased approximately 1 ton.
**One-half of lime should be disked in prior to plowing and one-half after plowing.

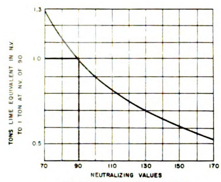


Fig. 2. — **Conversion chart to determine amounts of limestone of various neutralizing value (N.V.) that are equivalent to 1 ton lime with N.V. of 90.**

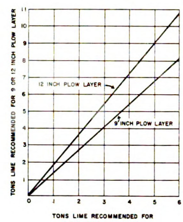


Fig. 3. — Diagram to convert recommendations made for a 6⅔-inch plow layer to recommendations for a 9- or 12-inch plow layer.

CITATION 2

Measuring Lime Needs

Measurements of soil pH, as made in the county soil testing laboratories, are used to determine if a soil should be limed. Lime needs can then be estimated from Table 3 on the basis of soil pH, soil texture and plowing depth.

In the state soil-testing laboratory at Michigan State University, a lime-requirement test is made in which both active hydrogen, or pH, and exchangeable hydrogen and aluminum, or potential acidity, are measured. This gives a more precise determination of lime requirement than the estimates made from soil pH and soil texture. However, satisfactory results are usually obtained from Table 3; any errors in lime recommendations usually result in underliming rather than overliming, so that additional lime may be applied after the soil is retested.

Lime recommendations made in either the state or county laboratories are in terms of the amount of ground limestone, with a neutralizing value of 90%, required to raise the pH of a 6 2/3-inch plow layer to pH 6.5.

From fields on which alfalfa is to be grown, a pH value between 6.8 and 7.0 is desirable; consequently, the recommendation from Table 4 should be used. For some crops where lower pH values may be desirable, the recommendations can be decreased accordingly.

Table 3. Tons of limestone to raise pH of plow layer of different soils to pH 6.5.

Texture of the plow layer	Depth of plowing	Soil pH				
		4.5-4.9	5.0-5.4	5.5-5.9	6.0-6.1	6.2
Sands and loamy sands	6 2/3	3.0	2.5	2.0	1.5	1.0
	9	4.0	3.5	2.5	2.0	1.5
	12	5.5	4.5	3.5	3.0	2.0
Sandy loams	6 2/3	4.0	3.0	2.5	1.5	1.0
	9	5.5	4.0	3.5	2.0	1.5
	12	7.0	5.5	4.5	3.0	2.0
Loams and silt loams	6 2/3	6.5	5.5	4.5	3.5	3.0
	9	9.0	7.5	6.0	5.0	4.0
	12	12.0	10.0	8.0	6.5	5.5

Table 4. Lime requirements for Alfalfa. Tons of limestone to raise pH of plow layer of different soils to pH 6.8 or 7.0.

Texture of the plow layer	Depth of plowing	Soil pH				
		4.5-4.9	5.0-5.4	5.5-5.9	6.0-6.1	6.2
Sands and loamy sands	6 2/3	4.0	3.5	3.0	2.5	2.0
	9	5.5	5.0	4.0	3.5	2.5
	12	7.0	6.5	5.5	4.5	3.5
Sandy loams	6 2/3	5.0	4.0	3.5	2.5	2.0
	9	7.0	5.5	4.5	3.5	2.5
	12	9.0	7.0	6.0	4.5	3.5
Loams and silt loams	6 2/3	7.5	6.5	5.5	4.5	4.0
	9	10.0	9.0	7.5	6.0	5.5
	12	13.5	12.0	10.0	8.0	7.0

Laboratory Section B using the revised lime information obtained correct answers for the problem. These figures are interpreted as strong evidence that use of inclusive tables that require only one step to obtain a lime requirement value are easier to use and result in more accurate results than information requiring the user to proceed through several steps to obtain this information.

Summary of comparisons of "Know Your Soils" and the Sanilac Report. In summary, the effectiveness of the 1964 "Know Your Soils" as a means of communicating soil management and soil survey information was compared with the Sanilac Soil Survey Report as a source of similar information. These two sources were compared using students from two college agricultural classes. "Know Your Soils" was used with a laboratory section of an Agronomy 1 class and with half of a Soil Fertility class, randomly split. The Sanilac Soil Survey was used with a second laboratory section of the Agronomy 1 class and with the other half of the Soil Fertility class. Subsequently, the two Soil Fertility class groups were given soil management problems requiring use of the respective sources of information to determine the answers.

The Soil Fertility students using "Know Your Soils," group 6a, was the only group that showed a statistically significant increase in their mean total score as a result of the initial treatment, Table 21. In the items of section I of the evaluation test, given as a pretest and posttest, the 12% increase obtained from use of "Know Your Soils" showed no further increase after treatment with the management problem, Table 22. Items 6 and 7 dealing with soil management group characteristics showed consistent increases among all groups tested.

In test section II, Agronomy 1 students using "Know Your Soils," group 5a, and those using the Sanilac Report, group 11a, showed nearly equal increases although these were not significant at the .05 level, Table 23. The Soil Fertility groups, 6a and 14a, also showed moderate relatively similar increases as a result of their respective treatments although these were also not significant at the .05 level. Subsequent treatment of these two groups with a soil management problem caused still further increases to approximately 20% for both groups and this increase was significant for the 14b group, using the Sanilac Report. Item 17, dealing with the natural drainage of the soil as determined from the management unit symbol, showed the greatest consistent increase among all groups and treatments. With only one exception, item 15, dealing with texture of the surface soil, showed decreased scores as a result of all treatments. This decrease is probably attributable to confusion in students minds concerning texture of the surface soil (the plow layer) as given in the soil type name, compared to the average profile texture as stressed in soil management group names and symbols.

In section III of the test, the Agronomy 1 group using "Know Your Soils" showed a significant 23% increase as a result of the treatment while the Agronomy 1 group using the Sanilac Report had a non-significant 16.6% increase, Table 24. The "Know Your Soils" treatment for the Soil Fertility group, 6a, showed a significant 18.8% increase. The Sanilac Report treatment for the Soil Fertility group, 14a, gave only a non-significant 8.4% increase. Subsequent problem treatments to the two groups increased scores for the group using "Know Your Soils" to 32.7% and for the group using the Sanilac Report to 25.9%, both of which were significant compared to their pretest scores. The increases due to "Know Your Soils" treatments for both the Agronomy 1 students and the Soil Fertility students were attributable to items dealing with basic concepts of the soil management group system of nomenclature stressed in this section of the evaluation. Items increasing most as the result of the Sanilac treatment for Agronomy 1 students were those that were not directly covered in the Sanilac Soil Survey Report and it is probable that these students had learned sufficient about the connotative symbol system of management groups to deduce these for groups which they had not been directly exposed to. The subsequent problem treatment for both classes resulted primarily in increases on items relating to understanding of the soil management group symbols.

In section IV of the test, the Agronomy 1 students using "Know Your Soils," group 5a, showed a slight non-significant increase and those using the Sanilac Report, group 11a, had a small non-significant decrease in scores as a result of their respective treatments, Table 24. The latter, however, are based on only the items in part IV-A of the test. The Soil Fertility students, on the other hand, had a significant 22% increase as a result of the "Know Your Soils" treatment and a further increase to 38.9% after working the management problem. In contrast with this, the Soil Fertility students using the Sanilac Report, group 14, had no change in score following either use of the report or the subsequent problem treatment.

Students using "Know Your Soils" and those using the Sanilac Report had relatively high initial scores on items dealing with soil texture and plowing depth as related to soil lime needs, items 30 to 32. These scores were not appreciably changed as a result of the

Sanilac Report or "Know Your Soils" treatments.

The appreciable increases in scores of Soil Fertility students using "Know Your Soils" was caused by items dealing with critical soil test values and soil erosion control factors given in the universal soil loss equation. The groups of students using the Sanilac Report knew little and learned nothing about information in sections IV-B and IV-C dealing with critical soil test values and characteristics of the universal soil loss equation. The lack of increase in this group is reasonable as the Sanilac Report contained no information on these subjects. The near zero change in scores on items of this section, not covered by the treatment material are important for they give confidence in positive scores as indicators of learning due to treatment with a source of information, Table Q in Appendix A. The increased learning on these subjects by the group using "Know Your Soils" suggests that these students (also with little previous knowledge about the subject) may have been interested in this type of information as a result of class work and were particularly aware of the material presented in "Know Your Soils" concerning it. Student scores on these items using "Know Your Soils" further increased as a result of the problem treatment while only a small positive gain was shown by those using the Sanilac Report.

The single table presentation of lime requirement values was used much more accurately by students working the soil management problem on lime needs than the multiple step procedure needed to determine lime requirements in the 1964 "Know Your Soils."

3. A Comparison of "Know Your Soils," the Sanilac Soil Survey Report, And a Teaching Program on Relative Effectiveness in Communicating Information on Soil Management Groups

Comparisons of the relative effectiveness of communication of soil management group information were made by comparing learning with use of: a Teaching Program devised by the author (Appendix H), information presented in the 1964 "Know Your Soils" circular, Appendix G, and the information in the Sanilac Soil Survey Report, (Schneider, 1961).

The Teaching Program dealt specifically with soil management groups, their symbols and their characteristics. The two other sources of information covered a much broader range of topics.

Two groups of Agronomy 1 students were given the Teaching Program, a third group was given the Sanilac Report and a fourth group was given the "Know Your Soils" circular. The differences in their pretest and posttest scores, Table 26, were compared on all items dealing with soil management groups to evaluate the learning of this type of information from the three different sources. These items included items 6, 7, 16, 17, and 22 to 29.

The mean percent increase on these items for the various groups, Table 26, was 47% (group 12a) and 39% (group 13a) for the two groups of students using the Teaching Program. These results with the Teaching Program compare to a 23% increase for the students, using "Know Your Soils" (group 5a) and 15% increase for the students using the Sanilac Soil Survey Report (group 11a). All were significant at the .05 level.

Table 26. Pretest scores and changes in scores, in percent, of Agronomy 1 students using the 1964 "Know Your Soils," the Sanilac Soil Survey Report, or the Teaching Program as sources of information on soil management groups. (The designations for each student group is shown in parenthesis in the column headings.)

Test Item	"Know Your Soils" (5a) 26 students		Sanilac Report (11a) 24 students		Teaching Program (12a) 17 students		Teaching Program (13a) 22 students	
	Pretest	Change	Pretest	Change	Pretest	Change	Pretest	Change
				Section I				
6	77	15	75	-21	59	35	64	36
7	54	31	58	17	71	24	64	23
				Section II				
16	15	15	4	21	12	47	5	54
17	23	31	25	28	29	41	64	23
				Section III				
22	31	42	21	8	35	47	32	41
23	8	4	0	33	0	65	0	45
24	27	35	33	-17	29	65	23	64
25	8	31	4	33	17	70	0	82
26	0	4	0	37	0	6	0	9
27	4	12	8	13	6	53	5	23
28	4	38	13	8	6	65	9	36
29	0	19	13	17	0	47	5	27
Mean score	21	23*	21	15*	22	47*	23	39*
Posttest score	44		36		69		62	

*Significant at .05 level.

Students using the Teaching Program had only small increases in scores on item 26. These results are reasonable as the item analysis indicated this item to be the most difficult on the entire test. They are also reasonable on a basis of the item content. Response to this item was to be the identification of the soil management group symbol which represented a poorly drained soil with 11 inches of sand over bedrock. Most persons replying to this, that were familiar with the system for designating the soil management groups, indicated this as a 4/Rc management group which is a management group of poorly drained soils, having sand over bedrock but which must have 18 to 42 inches of sand above the solid rock. The shallow depth of the sand stated in item 26 required that the management group should be given simply as Rc. It was on this basis that most persons answered incorrectly. All other items in this group had increases in score ranging from 23% to 82% for the groups using the Teaching Program.

Changes in score for the students using "Know Your Soils" (group 5a) and the Sanilac Report (group 11a) ranged from -17% to +42%, by items. Answers by students using the Teaching Program, to items in section II, (Tables O and P, Appendix A), not specifically covered in the Teaching Program, had changes no greater than would be expected due to random variability. This gives support to the conclusion that increases on items in Table 26 were caused by the Teaching Program rather than by chance differences.

An exception to the above is the sizeable decrease noted in item 15 for groups 12a and 13a. This decrease as noted previously is probably caused by students who mistakenly used the average profile texture represented in the management unit symbol for the surface soil texture as represented in the soil type name.

In summary, the mean increase of all students using the Teaching Program, 43%, was markedly greater than the mean increase of the students using "Know Your Soils," 23%, or the Sanilac Report, 15%, on the 12 items dealing with soil management groups. These data are interpreted as giving strong support to the very reasonable hypothesis that intensive training in a limited area of subject matter will give greater learning in that area than does a broad exposure to more extensive subject matter that includes this same information.

SUMMARY AND CONCLUSIONS

This study is part of a continuing effort to increase the effectiveness of communicating soil management and soil survey information to potential users. Previous work included the writing and distribution of the Odessa Township Interim Soil Survey Report. Its effectiveness was investigated and reported by Parsay (1957). Information obtained on weaknesses, problems, and strengths from that study was used to improve the writing of a soil management circular, the 1962 "Know Your Soils" (Appendix F). This circular was evaluated by distributing it for use by a group of agricultural extension agents. The agents were subsequently interviewed to obtain their evaluations of the circular. A training and evaluation seminar requested by the agents was subsequently held. This gave further opportunity to evaluate the usefulness of the circular in communicating soil management information and to determine changes needed to improve its effectiveness.

The circular was revised as the 1964 "Know Your Soils." Improvements in it included: (1) reorganization into independent sections, (2) revision for increased accuracy and clarity, and (3) inclusion of useful additional information. The revised edition was extensively tested with a wide range of potential user groups. These included vocational agriculture students, farmers, college students, vocational agriculture teachers, professional soil conservation personnel and university soil science staff. It was compared with the Sanilac County Soil Survey Report and a Teaching Program on soil management groups as sources of soil management group information.

The effectiveness of "Know Your Soils" and the Sanilac Report were measured both before and after working a soil management problem.

A test was written to measure how much individuals knew about soils and soil management information. It was given as a pretest and as a posttest to determine if additional information had been gained as the result of using "Know Your Soils." It was also used as a post-posttest to measure further learning after working a soil management problem by some users.

The effectiveness of the evaluation test was measured by reviewing score changes in test items on information not covered in the Sanilac Report or the Teaching Program. Lack of score increases on these items indicates that students did not obtain random increase on items for which they did not have information. Review of such items for the Teaching Program showed a slight average decrease in score for the entire test. An average decrease occurred in section I items and a slight increase occurred in sections II and IV items. The test also gave clear evidence, as illustrated in item 15, that confusion may cause decrease in learning. In this item confusion on the difference between average texture of a profile given in a management group symbol, and surface soil texture given as a part of a soil type name, caused students to answer incorrectly when they used the management group texture by mistake. In general, students learning the most about the management group system showed the greatest decrease in score on this item. These observations illustrate that the test effectively measured decreases where they occurred. Increase in learning was clearly indicated in section I (items 6 and 7), section II (items 16 and 17), and section III by groups 12a and

13a who used the Teaching Program that covered information on these items. The above three illustrations give evidence that the evaluation test was able to measure increases, decreases, or lack of change in learning.

The effectiveness of communication by "Know Your Soils" and other sources can be summarized by examining the changes in test scores for low capability groups, medium capability groups, and high capability groups as indicated by pretest scores of the groups. On this basis, groups 1, 2, and 3 were classified as low capability; groups 4, 5, 6, 11, 12, 13, and 14 were classified as medium capability; and groups 7, 8, 9, and 10 were classified as high capability.

Low capability groups 1 and 2, consisting of the vocational agriculture students, received little benefit from their exposure to "Know Your Soils" as indicated by their small change in scores. This may have been due to a lack of motivation, boredom at having to take the same test repeatedly, or insufficient background knowledge to give them a base from which to learn new information. The farmer soil extension class, group 3, also showed little benefit from their exposure to "Know Your Soils." This probably resulted from lack of background knowledge on the majority of the items as contrasted to the fact that they did have a notable increase on two items dealing with critical soil test values which was in an area of information that these farmers probably were acquainted with through their participation in an Extension soil test program. Low overall test scores probably did not result from lack of interest as these farmers volunteered to participate in the soil training session.

The addition of a problem as a treatment for groups 1 and 2 improved their scores despite the possible problem of boredom on tests. These increases were not significant with the exception of the scores for group 1b on section III of the test where a 14% increase was significant.

"Know Your Soils" was much more effective in communicating soil management information to the medium capability groups. This was illustrated by significant increases on the overall test for all groups. Added instruction given as lecture material to the Soils 1 class, group 4a, resulted in a notable increase on items covered in the lecture. Soil Fertility students with a background of information in soil management from their course were able to show a significant increase of learning on section I of the test that required increased knowledge over a broad range of subjects. Students scores increased markedly on items requiring an understanding of information needed in the working of a management problem, thus indicating the highly beneficial effect of a problem used with the "Know Your Soils" circular with these groups.

A comparison of "Know Your Soils" and the Sanilac Report used as treatments with these groups showed that all students benefited from the addition of a problem. It was also learned that students using the Sanilac Report were able to identify certain soil management group symbols on the test even though those symbols were not in the Sanilac Report. This apparently illustrates, that students in the medium capability groups are able to identify unfamiliar capability groups from their connotative symbols after learning the basic system of group symbols.

More students using the Sanilac Report in conjunction with a management problem were able to obtain correct lime requirement values in answer to a question on this subject than students using the 1964 "Know Your Soils" as a source of information. Further investigation showed that a single step table as found in the Sanilac Report, is used more accurately than a multi-step procedure, needed to use the 1964 "Know Your Soils" lime section, which was the Michigan Lime Bulletin (Doll, 1964).

A comparison among the score increases of students using "Know Your Soils," the Sanilac Report, and the Teaching Program, showed that the Teaching Program gave average total test score increases greater than those of "Know Your Soils" or the Sanilac Report. This was unexpected as the Teaching Program only provided information for answering 12 of the 40 test items. However, appreciable increases in scores occurred only on those 12 items. These results suggest that greater total learning may occur when a limited amount of information is thoroughly covered than when a broader scope of information is given less thorough coverage.

The effect of treatments on high capability groups demonstrated their ability to make significant increases in scores despite relatively high initial scores. This was evident in test section I where both the Edaphology class, group 8a, and the Soil Conservation Service personnel, group 10a, made significant increases. This is notable since a statistically significant increase is difficult to attain on the true and false type of questions especially since they represent a broad range of information. This may demonstrate that persons with a reasonable level of capability and above average knowledge in the area of soil management are able to perceive and learn new knowledge that applies to this area more effectively than persons with a less thorough background. Item 26 was difficult for most individuals even in this high capability group since it required knowledge not only of the basic management group symbols, but also of critical depth limits that must be considered in determining a management group.

These high capability groups also did poorly on item 15 after the "Know Your Soils" treatment and their scores decreased further after the problem treatment, probably because of confusion of the plow layer texture (given in the soil type name) with the average texture of the profile used in the soil management groups.

RECOMMENDATIONS

For improving the 1964 "Know Your Soils."

1. Include a more detailed table of contents in the front of "Know Your Soils."
2. Revise fertilizer table headings to explain meaning of High and Low for phosphorus and potassium, or use the newer "Fertilizer Bulletin."
3. Clarify and expand on the following soil classification subjects and relationships,
   a. The soil mapping unit symbol,
   b. The soil type name and the texture of the plow layer,
   c. The soil management unit symbol and the significance of its various parts.
4. Print the circular in an appealing and easily readable form.
5. Consider inclusion of the following additional topics:
   a. The land use capability unit and its meaning in relation to the above information,
   b. Information for other users: engineers, urban planners, foresters, horticulturists and land appraisers, and
   c. Economic significance of soil information for the above users.

For improving effectiveness of the evaluation test.

1. Eliminate items 1 and 2 as they deal with information that is nonessential in soil management.

2. Replace the true and false items with multiple choice items, and score items of different test sections to make each section equivalent on a 0 to 100 scale.
3. Change the form of items 30 to 32 to matching or multiple choice to aid in ease and accuracy of scoring.
4. Replace 4 of the 6 items (35 to 40) on factors of the universal soil loss equation with items giving a more comprehensive coverage of soil erosion control.
5. Use a minimum of 12 items per section to give a better statistical sample.

For additional research.

Research is needed on the motivation, quantity and level of information, most effective for low capability groups. This should include the testing of Teaching Programs for groups such as vocational agriculture students and farmers or interested individuals in those groups. The possibility of using limited amounts of information, such as individual sections of "Know Your Soils," with accompanying instruction for these groups, should be investigated. The possibility of increasing communication with vocational agriculture students through increased motivation should be investigated. This could be investigated by using real "home farm problems," to be solved in part by using "Know Your Soils."

Further research is needed to establish lime requirement values for use in lime requirement tables. This should include a test of the accuracy of lime requirement tables based on pH and soil texture by comparing them with values obtained from the "buffer method."

This could be accomplished by performing a correlation on data from samples submitted to the soil test laboratory since March 1963. The comparison of lime requirement and pH should be made at .5 pH increments for important textural classes or this might also be presented as a scatter diagram. The investigation should include analyses on a representative sample of the hand textured samples from the soil test laboratory to determine whether hand texturing is placing soils in their proper textural class. This study should be accompanied by a test of accuracy of above requirements by measuring actual field crop responses.

The advantages and disadvantages of using the total 1964 "Know Your Soils", or a revision of that circular, versus giving persons only those sections needed for their particular farm operation should be investigated.

BIBLIOGRAPHY

Adkins, Dorothy C., et al. 1947. Construction and analysis of achievement tests. US Government Printing Office, Washington.

Bauer, Kurt W. 1966. Application of soils studies in comprehensive regional planning. In Soil surveys and land use planning. Published by the Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin. Chapter 6, pp. 42-59.

Bender, William H. 1961. Soils suitable for septic tank filter fields. USDA Soil Cons. Ser., Bull. 243.

Bidwell, O. W., and R. A. Bohannon. 1960. Saline County, Kansas, promotes its soil survey. Reprint from Journal of Soil and Water Conservation. Vol. 15, No. 3.

Doll, E. C. 1964. Lime for Michigan soils. Cooperative Extension Service, Michigan State University, East Lansing, Michigan, Bull. 471.

Galloway, Harry M. 1966. Soil surveys and urban development--an educational approach. In Soil surveys and land use planning. Published by the Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin. Chapter 15, pp. 137-146.

Kellogg, Charles E. 1966. Soil surveys for community planning. In Soil surveys and land use planning. Published by the Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin. Chapter 1, pp. 1-7.

Lionberger, Herbert. 1960. Adoption of new ideas and practices. The Iowa State University Press, Ames, Iowa.

Longnecker, E. D. 1963. How to take accurate soil samples. Cooperative Extension Service, Michigan State University, East Lansing, Michigan.

Mawby, Russell G., and Cecil B. Haver. 1961. Types and sources of information used by farmers. Chapter 2 In A study of managerial processes of midwestern farmers. Glenn L. Johnson, Albert H. Halter, Harald R. Jensen, and D. Woods Thomas, Editors. Iowa State Univ. Press, Ames, Iowa.

Michigan State Highway Department. 1960. Field manual of soil engineering. (4th edition). Lansing, Michigan.

Moon, J. W., et al. 1938. Soil survey of Saginaw County, Michigan. USDA in cooperation with the Mich. Agr. Exp. Sta., Series 1933, No. 19.

Morris, John G. 1966. The use of soils information in urban planning and implementation. In Soil surveys and land use planning. Published by the Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin. Chapter 5, pp. 37-41.

Newbury, Raymond L., et al. 1961. Ela Township, Lake County, Illinois, Soil Survey Report, USDA-SCS in cooperation with Ela Area Planning Board, Lake County Regional Planning Commission, Lake County Health Department and the University of Illinois Agricultural Experiment Station.

Parsey, John M. 1957. Use and usefulness of a simplified soil survey report. National Project in Agricultural Communications. Mimeographed 99 pages. Michigan State University, East Lansing, Michigan.

Porter, James, Stanley Alfred, Eugene Whiteside, and Robert Lucas. Get the most from your farmland, soil survey summary for Odessa Township (an interim report). Michigan State College Cooperative Extension Service, East Lansing, Michigan. 1955.

Priest, T. W., E. P. Whiteside, and W. H. Heneberry. 1963. Use of soil management groups and related information in evaluation of farmlands and their utilization. Reprint from Soil Sci. Soc. Amer. Proc. 27:335-339.

Schneider, Ivan, et al. 1960. Soil survey of Montcalm County, Michigan. USDA in cooperation with the Mich. Agr. Exp. Sta., Series 1949, No. 11.

Schneider, Ivan, et al. 1961. Soil survey of Sanilac County, Michigan. USDA in cooperation with the Mich. Agr. Exp. Sta., Series 1953, No. 10.

Smith, Guy D., Andrew R. Aandahl. 1957. Soil classification and surveys. In Soil. Yearbook Agr. (US Dep Agr) US Government Printing Office, Washington. p. 397.

Soil Science and Horticulture Departments. 1963. Fertilizer recommendations for Michigan crops. Cooperative Extension Service, Michigan State University, East Lansing, Michigan.

Sorenson, Douglas. 1957. Factors influencing knowledge of technical soils concepts by Wisconsin farmers. Dept. of Agr. Journalism. Col. of Agr. University of Wisconsin. Bull. 27.

Southern Regional Soil Survey Work-Planning Conference. 1962. Comm. X Mississippi State University. Improvement of methods of informing the public or users of information in the published soil survey report. Mimeographed 6 pages.

Striker, M. M., and L. I. Harmon. 1961. Soil survey Lenawee County, Michigan. USDA in cooperation with the Mich. Agr. Exp. Sta., Series 1947, No. 10.

Thornburn, Thomas H. 1966. The use of agricultural soil surveys in the planning and construction of highways. In Soil surveys and land use planning. Published by the Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin. Chapter 9, pp. 87-103.

Van Eck, W. A., and E. P. Whiteside. 1958. Soil classification as a tool in predicting forest growth. (Mimeographed 12 p.) Taken from "First North American Forest Soils Conference, Sept. 8-11, 1958, pages 218-225. Agr. Exp. Sta., Michigan State University, East Lansing, Michigan.

Wenner, Kenneth, et al. 1964. Soil survey of Munster, Indiana. Through the cooperation of the Soil Conservation Service, the Lake County Cooperative Soil Survey, the Munster Chamber of Commerce and the Cooperative Extension Service.

Wilcoxon, F. 1958. Some rapid approximate statistical procedures, New York, American Cyanamid Co., 1949, p. 13, quoted In Virginia L. Senders, Measurement and statistics, New York, Oxford University Press, pp. 489-491.

Wischmeier, Walter H. 1960. Cropping-management factor evaluations for a universal soil-loss equation. Soil Sci. Soc. Am. Proc. 24:322-326.

APPENDICES

APPENDIX A

TABLES OF DATA FOR ITEMS 1 TO 40 FOR GROUPS 1 TO 14

Table A. Total test evaluation for group 1a (18 vocational agriculture students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	5.6	55.6	22.2	16.7	- 5.6
2	61.2	5.6	11.1	22.2	+11.1
3	0.0	66.7	22.2	11.1	-11.1
4	22.2	38.9	27.8	11.1	-16.7
5	5.6	66.7	27.8	0.0	-27.8
6	38.9	11.1	27.8	22.2	- 5.6
7	38.9	16.7	16.7	27.8	+11.1
8	38.9	11.1	22.2	27.8	+ 5.6
9	50.0	27.8	0.0	22.2	+22.2
10	55.6	5.6	11.1	27.8	+16.7
11	22.2	27.8	16.7	33.4	+16.7
12	61.2	11.1	5.6	22.2	+16.7
13	50.0	5.6	22.2	22.2	+ 0.0
14	33.4	38.9	16.7	11.1	- 5.6
			Section II		
15	11.1	72.3	5.6	11.1	+ 5.6
16	0.0	72.3	11.1	16.7	+ 5.6
17	22.2	44.5	11.1	22.2	+11.1
18	16.7	27.8	11.1	44.5	+33.4
19	27.8	22.2	22.2	27.8	+ 5.6
20	16.7	38.9	5.6	38.9	+33.4
21	16.7	66.7	11.1	5.6	- 5.6
			Section III		
22	0.0	72.3	11.1	16.7	+ 5.6
23	0.0	94.6	0.0	5.6	+ 5.6
24	0.0	89.0	11.1	0.0	-11.1
25	0.0	100.0	0.0	0.0	0.0
26	0.0	100.0	0.0	0.0	0.0
27	0.0	89.0	5.6	5.6	0.0
28	0.0	94.6	5.6	0.0	- 5.6
29	0.0	94.6	5.6	0.0	- 5.6
			Section IV-A		
30	11.1	50.0	11.1	27.8	+16.7
31	27.8	33.4	16.7	22.2	+ 5.6
32	22.2	38.9	16.7	22.2	+ 5.6
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	100.0	0.0	0.0	0.0
			Section IV-C		
35	0.0	100.0	0.0	0.0	0.0
36	0.0	100.0	0.0	0.0	0.0
37	0.0	100.0	0.0	0.0	0.0
38	0.0	100.0	0.0	0.0	0.0
39	0.0	100.0	0.0	0.0	0.0
40	0.0	100.0	0.0	0.0	0.0

Table B. Total test evaluation for group 1b (18 vocational agriculture students) from pretest to post-posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	5.6	50.0	22.2	22.2	0.0
2	72.3	11.1	0.0	16.7	+16.7
3	5.6	66.7	16.7	11.1	- 5.6
4	22.2	27.8	27.8	22.2	- 5.6
5	5.6	50.0	27.8	16.7	-11.1
6	55.6	5.6	11.1	27.8	+16.7
7	33.4	0.0	22.2	44.5	+22.3
8	61.2	22.2	0.0	16.7	+16.7
9	33.4	11.1	16.7	38.9	+22.2
10	38.9	11.1	27.8	22.2	- 5.6
11	16.7	16.7	22.2	44.5	+22.3
12	55.6	16.7	11.1	16.7	+ 5.6
13	55.6	27.8	16.7	0.0	-16.7
14	22.2	33.4	27.8	16.7	-11.1
			Section II		
15	5.6	61.2	11.1	22.2	+11.1
16	0.0	83.4	11.1	5.6	- 5.5
17	16.7	61.2	16.7	5.6	-11.1
18	27.8	27.8	0.0	44.5	+44.5
19	38.9	33.4	11.1	16.7	+ 5.6
20	16.7	66.7	5.6	11.1	+ 5.5
21	11.1	66.7	16.7	5.6	-11.1
			Section III		
22	5.6	44.5	5.6	44.5	+38.9
23	0.0	89.0	0.0	11.1	+11.1
24	5.6	66.7	5.6	22.2	+16.6
25	0.0	89.0	0.0	11.1	+11.1
26	0.0	100.0	0.0	0.0	0.0
27	0.0	89.0	5.6	5.6	0.0
28	0.0	83.4	5.6	11.1	+ 5.5
29	0.0	61.2	5.6	33.4	+27.8
			Section IV-A		
30	0.0	44.5	22.2	33.4	+11.2
31	16.7	38.9	27.8	16.7	-11.1
32	22.2	38.9	16.7	22.2	+ 5.5
			Section IV-B		
33	0.0	77.8	0.0	22.2	+22.2
34	0.0	89.0	0.0	11.1	+11.1
			Section IV-C		
35	0.0	89.0	0.0	11.1	+11.1
36	0.0	94.6	0.0	5.6	+ 5.6
37	0.0	100.0	0.0	0.0	0.0
38	0.0	94.6	0.0	5.6	+ 5.6
39	0.0	100.0	0.0	0.0	0.0
40	0.0	100.0	0.0	0.0	0.0

Table C . Total test evaluation for group 2a (18 vocational agriculture students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	5.6	61.2	22.2	11.1	-11.1
2	44.5	16.7	38.9	0.0	-38.9
3	16.7	55.6	27.8	0.0	-27.8
4	11.1	44.5	22.2	22.2	0.0
5	38.9	16.7	11.1	33.4	+22.3
6	27.8	0.0	38.9	33.4	- 5.5
7	27.8	33.4	22.2	16.7	- 5.5
8	50.0	22.2	22.2	5.6	-16.6
9	50.0	5.6	33.4	11.1	-22.3
10	33.4	5.6	27.8	33.4	+ 5.6
11	38.9	27.8	5.6	27.8	+22.2
12	55.6	11.1	27.8	5.6	-22.2
13	38.9	16.7	33.4	11.1	-22.3
14	27.8	33.4	22.2	16.7	- 5.5
			Section II		
15	0.0	72.3	22.2	5.6	-16.6
16	0.0	77.8	11.1	11.1	0.0
17	22.2	61.2	5.6	11.1	+ 5.5
18	16.7	50.0	22.2	11.1	-11.1
19	27.8	50.0	16.7	5.6	-11.1
20	0.0	61.2	27.8	11.1	-16.7
21	11.1	55.6	27.8	5.6	-22.2
			Section III		
22	0.0	83.4	5.6	11.1	+ 5.5
23	0.0	100.0	0.0	0.0	0.0
24	0.0	61.2	16.7	22.2	+ 5.5
25	0.0	94.6	0.0	5.6	+ 5.6
26	0.0	100.0	0.0	0.0	0.0
27	0.0	100.0	0.0	0.0	0.0
28	0.0	94.6	5.6	0.0	- 5.6
29	5.6	89.0	5.6	0.0	- 5.6
			Section IV-A		
30	11.1	61.2	0.0	27.8	+27.8
31	27.8	33.4	11.1	27.8	+16.7
32	44.5	11.1	22.2	22.2	0.0
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	100.0	0.0	0.0	0.0
			Section IV-C		
35	0.0	89.0	0.0	11.1	+11.1
36	0.0	89.0	0.0	11.1	+11.1
37	0.0	89.0	0.0	11.1	+11.1
38	0.0	83.4	0.0	16.7	+16.7
39	0.0	89.0	0.0	11.1	+11.1
40	0.0	94.6	0.0	5.6	+ 5.6

Table D. Total test evaluation for group 2b (18 vocational agriculture students) from pretest to post-posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	11.1	66.7	16.7	5.6	-11.1
2	77.8	0.0	5.6	16.7	+11.1
3	38.9	27.8	5.6	27.8	+22.2
4	11.1	50.0	22.2	16.7	- 5.5
5	22.2	33.4	27.8	16.7	-11.1
6	55.6	0.0	11.1	33.4	+22.3
7	27.8	27.8	22.2	22.2	0.0
8	33.4	16.7	38.9	11.1	-27.8
9	72.3	5.6	11.1	11.1	0.0
10	38.9	5.6	22.2	33.4	+11.2
11	22.2	22.2	22.2	33.4	+11.2
12	44.5	5.6	38.9	11.1	-27.8
13	66.7	11.1	5.6	16.7	+11.1
14	16.7	27.8	33.4	22.2	-11.2
			Section II		
15	0.0	66.7	22.2	11.1	-11.1
16	11.1	83.4	0.0	5.6	+ 5.6
17	5.6	66.7	22.2	5.6	-16.6
18	22.2	44.5	16.7	16.7	0.0
19	33.4	38.9	11.1	16.7	+ 5.6
20	11.1	55.6	16.7	16.7	0.0
21	16.7	55.6	22.2	5.6	-16.6
			Section III		
22	0.0	61.2	5.6	33.4	+27.8
23	0.0	100.0	0.0	0.0	0.0
24	5.6	61.2	11.1	22.2	+11.1
25	0.0	94.6	0.0	5.6	+ 5.6
26	0.0	100.0	0.0	0.0	0.0
27	0.0	100.0	0.0	0.0	0.0
28	0.0	83.4	5.6	11.1	+ 5.5
29	11.1	89.0	0.0	0.0	0.0
			Section IV-A		
30	5.6	55.6	5.6	33.4	+27.8
31	16.7	27.8	22.2	33.4	+11.2
32	44.5	16.7	22.2	16.7	- 5.5
			Section IV-B		
33	0.0	77.8	0.0	22.2	+22.2
34	0.0	83.4	0.0	16.7	+16.7
			Section IV-C		
35	0.0	77.8	0.0	22.2	+22.2
36	0.0	77.8	0.0	22.2	+22.2
37	0.0	94.6	0.0	5.6	+ 5.6
38	0.0	100.0	0.0	0.0	0.0
39	0.0	94.6	0.0	5.6	+ 5.6
40	0.0	100.0	0.0	0.0	0.0

Table E . Total test evaluation for group 3a (11 farmers attending an extension soils class) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	18.2	63.6	18.2	0.0	-18.2
2	81.8	0.0	0.0	18.2	+18.2
3	45.5	45.5	9.1	0.0	- 9.1
4	18.2	45.5	18.2	18.2	0.0
5	9.1	81.8	9.1	0.0	- 9.1
6	45.5	9.1	0.0	45.5	+45.5
7	63.6	9.1	9.1	18.2	+ 9.1
8	81.8	0.0	18.2	0.0	-18.2
9	54.6	27.3	0.0	18.2	+18.2
10	45.5	18.2	9.1	27.3	+18.2
11	36.4	18.2	36.4	9.1	-27.3
12	54.6	9.1	9.1	27.3	+18.2
13	72.7	9.1	9.1	9.1	0.0
14	36.4	45.5	9.1	9.1	0.0
			Section II		
15	0.0	72.7	27.3	0.0	-27.3
16	0.0	63.6	18.2	18.2	0.0
17	27.3	27.3	0.0	45.5	+45.5
18	27.3	36.4	27.3	9.1	-18.2
19	36.4	18.2	18.2	27.3	+ 9.1
20	0.0	81.8	18.2	0.0	-18.2
21	9.1	45.5	36.4	9.1	-27.3
			Section III		
22	45.5	9.1	0.0	45.5	+45.5
23	0.0	81.8	9.1	9.1	0.0
24	27.3	36.4	0.0	36.4	+36.4
25	0.0	27.3	0.0	72.7	+72.7
26	0.0	90.9	9.1	0.0	- 9.1
27	0.0	90.9	0.0	9.1	+ 9.1
28	9.1	63.6	9.1	18.2	+ 9.1
29	0.0	100.0	0.0	0.0	0.0
			Section IV-A		
30	0.0	81.8	9.1	9.1	0.0
31	36.4	9.1	0.0	54.6	+54.6
32	63.6	9.1	27.3	0.0	-27.3
			Section IV-B		
33	0.0	54.6	0.0	45.5	+45.5
34	9.1	54.6	0.0	36.4	+36.4
			Section IV-C		
35	0.0	81.8	0.0	18.2	+18.2
36	9.1	90.9	0.0	0.0	0.0
37	0.0	81.8	0.0	18.2	+18.2
38	0.0	90.9	0.0	9.1	+ 9.1
39	0.0	81.8	0.0	18.2	+18.2
40	0.0	90.9	0.0	9.1	+ 9.1

Table F. Total test evaluation for group 4a (64 Soils 1 students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	1.6	71.9	10.9	15.6	+ 4.7
2	78.1	3.1	6.3	12.5	+ 6.2
3	18.8	46.9	31.3	3.1	-28.2
4	23.4	37.5	21.9	17.2	- 4.7
5	10.9	59.4	14.1	15.6	+ 1.5
6	62.5	4.7	7.8	25.0	+17.2
7	51.6	12.5	9.4	26.6	+17.2
8	82.8	4.7	7.8	4.7	- 3.1
9	42.2	1.6	0.0	56.3	+56.3
10	43.8	12.5	15.6	28.1	+12.5
11	42.2	18.8	28.1	10.9	-17.2
12	40.6	7.8	31.3	20.3	-11.0
13	65.6	3.1	15.6	15.6	0.0
14	51.6	21.9	9.4	17.2	+ 7.8
			Section II		
15	25.0	34.4	29.7	10.9	-18.8
16	0.0	75.0	12.5	12.5	0.0
17	29.7	29.7	29.7	10.9	-18.8
18	45.3	7.8	10.9	35.9	+25.0
19	23.4	12.5	10.9	53.1	+42.2
20	20.3	20.3	23.4	35.9	+12.5
21	7.8	65.6	14.1	12.5	- 1.6
			Section III		
22	31.3	21.9	7.8	39.1	+31.3
23	0.0	53.1	1.6	45.3	+43.7
24	12.5	35.9	6.3	45.3	+39.0
25	3.1	62.5	6.3	28.1	+21.8
26	1.6	84.4	1.6	12.5	+10.9
27	1.6	81.3	3.1	14.1	+11.0
28	1.6	54.7	3.1	40.6	+37.5
29	1.6	70.3	7.8	20.3	+12.5
			Section IV-A		
30	18.8	53.1	14.1	14.1	0.0
31	46.9	23.4	15.6	14.1	- 1.5
32	60.9	15.6	12.5	10.9	- 1.6
			Section IV-B		
33	0.0	60.9	1.6	37.5	+35.9
34	0.0	57.8	0.0	42.2	+42.2
			Section IV-C		
35	0.0	21.9	0.0	78.1	+78.1
36	4.7	28.1	3.1	64.1	+61.0
37	3.1	21.9	1.6	73.4	+71.8
38	1.6	28.1	0.0	70.3	+70.3
39	1.6	21.9	0.0	76.6	+76.6
40	3.1	26.6	0.0	70.3	+70.3

Table G. Total test evaluation for group 5a (26 Agronomy 1 students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	7.7	57.7	34.6	0.0	-34.6
2	92.3	0.0	0.0	7.7	+ 7.7
3	11.5	65.4	11.5	11.5	0.0
4	19.2	50.0	19.2	11.5	- 7.7
5	19.2	38.5	38.5	3.9	-34.6
6	73.1	3.9	3.9	19.2	+15.3
7	38.5	0.0	15.4	46.2	+30.8
8	53.9	19.2	23.1	3.9	-19.2
9	88.5	3.9	0.0	7.7	+ 7.7
10	30.8	23.1	15.4	30.8	+15.4
11	42.3	11.5	19.2	26.9	+ 7.7
12	53.9	11.5	3.9	30.8	+26.9
13	61.5	15.4	11.5	11.5	0.0
14	53.9	7.7	19.2	19.2	0.0
			Section II		
15	15.4	34.6	38.5	11.5	-27.0
16	7.7	61.5	7.7	23.1	+15.4
17	11.5	34.6	11.5	42.3	+30.8
18	34.6	23.1	15.4	26.9	+11.5
19	42.3	19.2	23.1	15.4	- 7.7
20	73.1	11.5	3.9	11.5	+ 7.6
21	11.5	50.0	11.5	26.9	+15.4
			Section III		
22	23.1	19.2	7.7	50.0	+42.3
23	0.0	80.8	7.7	11.5	+ 3.8
24	15.4	26.9	11.5	46.2	+34.7
25	0.0	53.9	7.7	38.5	+30.8
26	0.0	96.2	0.0	3.9	+ 3.9
27	3.9	84.6	0.0	11.5	+11.5
28	3.9	57.7	0.0	38.5	+38.5
29	0.0	80.8	0.0	19.2	+19.2
			Section IV-A		
30	42.3	19.2	23.1	15.4	- 7.7
31	53.9	3.9	23.1	19.2	- 3.9
32	61.5	3.9	15.4	19.2	+ 3.8
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	96.2	3.9	0.0	- 3.9
			Section IV-C		
35	3.9	92.3	3.9	0.0	- 3.9
36	3.9	92.3	0.0	3.9	+ 3.9
37	0.0	88.5	3.9	7.7	+ 3.8
38	0.0	84.6	3.9	11.5	+ 7.6
39	0.0	88.5	3.9	7.7	+ 3.8
40	0.0	84.6	3.9	11.5	+ 7.6

Table H. Total test evaluation for group 6a (18 Soil Fertility students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	22.2	27.8	33.4	16.7	-16.7
2	50.0	5.6	22.2	22.2	0.0
3	16.7	33.4	22.2	27.8	+ 5.6
4	61.2	11.1	0.0	27.8	+27.8
5	55.6	11.1	11.1	22.2	+11.1
6	66.7	0.0	5.6	27.8	+22.2
7	27.8	22.2	11.1	38.9	+27.8
8	72.3	5.6	5.6	16.7	+11.1
9	100.0	0.0	0.0	0.0	0.0
10	16.7	38.9	5.6	38.9	+33.3
11	72.3	0.0	16.7	11.1	- 5.6
12	38.9	0.0	22.2	38.9	+16.7
13	55.6	5.6	5.6	33.4	+27.8
14	50.0	27.8	5.6	16.7	+11.1
			Section II		
15	38.9	16.7	33.4	11.1	-22.3
16	0.0	89.0	0.0	11.1	+11.1
17	5.6	27.8	5.6	61.2	+55.6
18	50.0	0.0	11.1	38.9	+27.8
19	27.8	5.6	22.2	44.5	+22.3
20	72.3	11.1	16.7	0.0	-16.7
21	38.9	11.1	16.7	33.4	+16.7
			Section III		
22	22.2	33.4	11.1	33.4	+22.3
23	0.0	89.0	0.0	11.1	+11.1
24	38.9	33.4	5.6	22.2	+16.6
25	5.6	44.5	5.6	44.5	+38.9
26	0.0	94.6	0.0	5.6	+ 5.6
27	0.0	77.8	0.0	22.2	+22.2
28	0.0	55.6	0.0	44.5	+44.5
29	5.6	61.2	22.2	11.1	-11.1
			Section IV-A		
30	61.2	22.2	11.1	5.6	- 5.5
31	72.3	16.7	5.6	5.6	0.0
32	72.3	11.1	11.1	5.6	- 5.5
			Section IV-B		
33	0.0	72.3	0.0	27.8	+27.8
34	0.0	61.2	0.0	38.9	+38.9
			Section IV-C		
35	16.7	27.8	5.6	50.0	+44.4
36	16.7	22.2	27.8	33.4	+ 5.6
37	16.7	27.8	5.6	50.0	+44.4
38	11.1	50.0	5.6	33.4	+27.8
39	11.1	27.8	11.1	50.0	+38.9
40	5.6	50.0	5.6	38.9	+33.3

Table I . Total test evaluation for group 6b (18 Soil Fertility students) from pretest to post-posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	16.7	27.8	38.9	16.7	-22.2
2	55.6	5.6	16.7	22.2	+ 5.5
3	16.7	38.9	22.2	22.2	0.0
4	55.6	16.7	5.6	22.2	+16.6
5	61.2	16.7	5.6	16.7	+11.1
6	72.3	0.0	0.0	27.8	+27.8
7	38.9	0.0	0.0	61.2	+61.2
8	55.6	5.6	22.2	16.7	- 5.5
9	100.0	0.0	0.0	0.0	0.0
10	16.7	38.9	5.6	38.9	+33.3
11	83.4	0.0	5.6	11.1	+ 5.5
12	33.4	11.1	27.8	27.8	0.0
13	50.0	0.0	11.1	38.9	+27.8
14	55.6	33.4	0.0	11.1	+11.1
			Section II		
15	27.8	16.7	44.5	11.1	-33.4
16	0.0	66.7	0.0	33.4	+33.4
17	11.1	22.2	0.0	66.7	+66.7
18	55.6	0.0	5.6	38.9	+33.3
19	44.5	11.1	5.6	38.9	+33.3
20	66.7	11.1	22.2	0.0	-22.2
21	50.0	5.6	5.6	38.9	+33.3
			Section III		
22	27.8	0.0	5.6	66.7	+61.1
23	0.0	89.0	0.0	11.1	+11.1
24	27.8	27.8	16.7	27.8	+11.1
25	5.6	27.8	5.6	61.2	+55.6
26	0.0	94.6	0.0	5.6	+ 5.6
27	0.0	50.0	0.0	50.0	+50.0
28	0.0	38.9	0.0	61.2	+61.2
29	16.7	55.6	11.1	16.7	+ 5.6
			Section IV-A		
30	55.6	22.2	16.7	5.6	-11.1
31	77.8	16.7	0.0	5.6	+ 5.6
32	77.8	11.1	5.6	5.6	0.0
			Section IV-B		
33	0.0	27.8	0.0	72.3	+72.3
34	0.0	38.9	0.0	61.2	+61.2
			Section IV-C		
35	22.2	22.2	0.0	55.6	+55.6
36	33.4	11.1	11.1	44.5	+33.4
37	22.2	27.8	0.0	50.0	+50.0
38	16.7	33.4	0.0	50.0	+50.0
39	16.7	22.2	5.6	55.6	+50.0
40	11.1	27.8	0.0	61.2	+61.2

Table J. Total test evaluation for group 7a (8 vocational agriculture teachers) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	12.5	50.0	25.0	12.5	-12.5
2	75.0	0.0	25.0	0.0	-25.0
3	12.5	62.5	25.0	0.0	-25.0
4	12.5	75.0	0.0	12.5	+12.5
5	25.0	37.5	25.0	12.5	-12.5
6	87.5	0.0	0.0	12.5	+12.5
7	62.5	0.0	12.5	25.0	+12.5
8	87.5	0.0	0.0	12.5	+12.5
9	75.0	0.0	0.0	25.0	+25.0
10	87.5	0.0	0.0	12.5	+12.5
11	50.0	12.5	25.0	12.5	-12.5
12	75.0	0.0	0.0	25.0	+25.0
13	62.5	37.5	0.0	0.0	0.0
14	75.0	12.5	12.5	0.0	-12.5
			Section II		
15	37.5	62.5	0.0	0.0	0.0
16	0.0	62.5	0.0	37.5	+37.5
17	75.0	25.0	0.0	0.0	0.0
18	87.5	12.5	0.0	0.0	0.0
19	62.5	12.5	12.5	12.5	0.0
20	50.0	12.5	12.5	25.0	+12.5
21	25.0	0.0	25.0	50.0	+25.0
			Section III		
22	62.5	0.0	0.0	37.5	+37.5
23	0.0	37.5	12.5	50.0	+37.5
24	62.5	12.5	12.5	12.5	0.0
25	12.5	12.5	0.0	75.0	+75.0
26	0.0	100.0	0.0	0.0	0.0
27	0.0	87.5	0.0	12.5	+12.5
28	25.0	0.0	0.0	75.0	+75.0
29	12.5	25.0	0.0	62.5	+62.5
			Section IV-A		
30	37.5	12.5	25.0	25.0	0.0
31	62.5	12.5	0.0	25.0	+25.0
32	62.5	12.5	0.0	25.0	+25.0
			Section IV-B		
33	12.5	37.5	0.0	50.0	+50.0
34	12.5	12.5	0.0	75.0	+75.0
			Section IV-C		
35	25.0	0.0	0.0	75.0	+75.0
36	12.5	25.0	0.0	62.5	+62.5
37	25.0	0.0	0.0	75.0	+75.0
38	0.0	0.0	0.0	100.0	+100.0
39	12.5	12.5	0.0	75.0	+75.0
40	12.5	12.5	0.0	75.0	+75.0

Table K. Total test evaluation for group 8a (12 Edaphology students) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	58.3	0.0	25.0	16.7	- 8.3
2	58.3	8.3	8.3	25.0	+16.7
3	58.3	25.0	8.3	8.3	0.0
4	50.0	33.3	8.3	8.3	0.0
5	58.3	16.7	0.0	25.0	+25.0
6	100.0	0.0	0.0	0.0	0.0
7	91.7	0.0	0.0	8.3	+ 8.3
8	91.7	0.0	0.0	8.3	+ 8.3
9	83.3	16.7	0.0	0.0	0.0
10	50.0	25.0	0.0	25.0	+25.0
11	75.0	8.3	8.3	8.3	0.0
12	50.0	16.7	8.3	25.0	+16.7
13	75.0	8.3	0.0	16.7	+16.7
14	91.7	0.0	8.3	0.0	- 8.3
			Section II		
15	58.3	41.7	0.0	0.0	0.0
16	33.3	41.7	8.3	16.7	+ 8.4
17	83.3	0.0	8.3	8.3	0.0
18	83.3	0.0	8.3	8.3	0.0
19	66.7	16.7	0.0	16.7	+16.7
20	66.7	16.7	8.3	8.3	0.0
21	66.7	8.3	16.7	8.3	- 8.4
			Section III		
22	91.7	0.0	8.3	0.0	- 8.3
23	33.3	33.3	16.7	16.7	0.0
24	83.3	0.0	0.0	16.7	+16.7
25	75.0	8.3	8.3	8.3	0.0
26	0.0	66.7	25.0	8.3	-16.7
27	25.0	41.7	16.7	16.7	0.0
28	75.0	25.0	0.0	0.0	0.0
29	50.0	33.3	0.0	16.7	+16.7
			Section IV-A		
30	58.3	33.3	0.0	8.3	+ 8.3
31	66.7	16.7	8.3	8.3	0.0
32	83.3	0.0	8.3	8.3	0.0
			Section IV-B		
33	16.7	25.0	0.0	58.3	+58.3
34	16.7	25.0	0.0	58.3	+58.3
			Section IV-C		
35	33.3	0.0	8.3	58.3	+50.0
36	25.0	8.3	8.3	58.3	+50.0
37	33.3	0.0	8.3	58.3	+50.0
38	16.7	25.0	8.3	50.0	+41.7
39	25.0	0.0	16.7	58.3	+41.6
40	16.7	41.7	0.0	41.7	+41.7

Table L. Total test evaluation for group 9a (3 Michigan State Soil Science Department staff) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	66.6	33.3	0.0	0.0	0.0
2	100.0	0.0	0.0	0.0	0.0
3	100.0	0.0	0.0	0.0	0.0
4	66.6	0.0	33.3	0.0	-33.3
5	100.0	0.0	0.0	0.0	0.0
6	100.0	0.0	0.0	0.0	0.0
7	100.0	0.0	0.0	0.0	0.0
8	100.0	0.0	0.0	0.0	0.0
9	100.0	0.0	0.0	0.0	0.0
10	100.0	0.0	0.0	0.0	0.0
11	100.0	0.0	0.0	0.0	0.0
12	100.0	0.0	0.0	0.0	0.0
13	66.6	0.0	0.0	33.3	+33.3
14	100.0	0.0	0.0	0.0	0.0
			Section II		
15	100.0	0.0	0.0	0.0	0.0
16	0.0	33.3	33.3	33.3	0.0
17	100.0	0.0	0.0	0.0	0.0
18	100.0	0.0	0.0	0.0	0.0
19	66.6	0.0	0.0	33.3	+33.3
20	100.0	0.0	0.0	0.0	0.0
21	66.6	33.3	0.0	0.0	0.0
			Section III		
22	100.0	0.0	0.0	0.0	0.0
23	66.6	0.0	0.0	33.3	+33.3
24	100.0	0.0	0.0	0.0	0.0
25	100.0	0.0	0.0	0.0	0.0
26	33.3	33.3	33.3	0.0	-33.3
27	100.0	0.0	0.0	0.0	0.0
28	66.6	0.0	0.0	33.3	+33.3
29	100.0	0.0	0.0	0.0	0.0
			Section IV-A		
30	100.0	0.0	0.0	0.0	0.0
31	100.0	0.0	0.0	0.0	0.0
32	100.0	0.0	0.0	0.0	0.0
			Section IV-B		
33	33.3	33.3	0.0	33.3	+33.3
34	33.3	33.3	0.0	33.3	+33.3
			Section IV-C		
35	0.0	0.0	0.0	100.0	+100.0
36	66.6	0.0	0.0	33.3	+33.3
37	33.3	0.0	0.0	66.6	+66.6
38	33.3	33.3	0.0	33.3	+33.3
39	0.0	33.3	0.0	66.6	+66.6
40	33.3	33.3	0.0	33.3	+33.3

Table M. Total test evaluation for group 10a (12 Soil Conservation Service personnel) from pretest to posttest using the 1964 "Know Your Soils."

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	66.7	16.7	0.0	16.7	+16.7
2	75.0	16.7	0.0	8.3	+ 8.3
3	25.0	41.7	16.7	16.7	0.0
4	33.3	58.3	0.0	8.3	+ 8.3
5	66.7	8.3	8.3	16.7	+ 8.4
6	91.7	0.0	0.0	8.3	+ 8.3
7	91.7	0.0	8.3	0.0	- 8.3
8	91.7	0.0	0.0	8.3	+ 8.3
9	75.0	0.0	8.3	16.7	+ 8.4
10	66.7	16.7	0.0	16.7	+16.7
11	83.3	0.0	8.3	8.3	0.0
12	50.0	25.0	8.3	16.7	+ 8.4
13	100.0	0.0	0.0	0.0	0.0
14	100.0	0.0	0.0	0.0	0.0
			Section II		
15	33.3	58.3	8.3	0.0	- 8.3
16	50.0	33.3	8.3	8.3	0.0
17	91.7	8.3	0.0	0.0	0.0
18	91.7	0.0	8.3	0.0	- 8.3
19	91.7	8.3	0.0	0.0	0.0
20	25.0	58.3	0.0	16.7	+16.7
21	75.0	8.3	0.0	16.7	+16.7
			Section III		
22	91.7	0.0	0.0	8.3	+ 8.3
23	33.3	33.3	0.0	33.3	+33.3
24	91.7	0.0	0.0	8.3	+ 8.3
25	83.3	0.0	8.3	8.3	0.0
26	25.0	50.0	8.3	16.7	+ 8.4
27	83.3	8.3	0.0	8.3	+ 8.3
28	75.0	16.7	0.0	8.3	+ 8.3
29	83.3	0.0	8.3	8.3	0.0
			Section IV-A		
30	50.0	16.7	0.0	33.3	+33.3
31	83.3	16.7	0.0	0.0	0.0
32	75.0	16.7	0.0	8.3	+ 8.3
			Section IV-B		
33	25.0	25.0	0.0	50.0	+50.0
34	33.3	25.0	0.0	41.7	+41.7
			Section IV-C		
35	91.7	8.3	0.0	0.0	0.0
36	83.3	0.0	0.0	16.7	+16.7
37	83.3	8.3	8.3	0.0	- 8.3
38	91.7	8.3	0.0	0.0	0.0
39	91.7	8.3	0.0	0.0	0.0
40	91.7	8.3	0.0	0.0	0.0

Table N. Total test evaluation for group 11a (24 Agronomy 1 students) from pretest to posttest using the Sanilac Report.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	8.3	70.8	16.7	4.2	-12.5
2	83.3	0.0	4.2	12.5	+ 8.3
3	16.7	45.8	16.7	20.8	+ 4.1
4	33.3	41.7	20.8	4.2	-16.6
5	12.5	41.7	33.3	12.5	-20.8
6	66.7	0.0	8.3	25.0	+16.7
7	50.0	12.5	8.3	29.2	+20.9
8	62.5	37.5	0.0	0.0	0.0
9	91.7	0.0	0.0	8.3	+ 8.3
10	29.2	25.0	29.2	16.7	-12.5
11	75.0	0.0	8.3	16.7	+ 8.4
12	54.2	12.5	20.8	12.5	- 8.3
13	50.0	20.8	12.5	16.7	+ 4.2
14	25.0	37.5	12.5	25.0	+12.5
			Section II		
15	29.2	41.7	12.5	16.7	+ 4.2
16	4.2	75.0	0.0	20.8	+20.8
17	12.5	41.7	12.5	33.3	+20.8
18	29.2	20.8	12.5	37.5	+25.0
19	20.8	33.3	29.2	16.7	-12.5
20	66.7	4.2	8.3	20.8	+12.5
21	12.5	45.8	16.7	25.0	+ 8.3
			Section III		
22	8.3	58.3	12.5	20.8	+ 8.3
23	0.0	66.7	0.0	33.3	+33.3
24	4.2	54.2	29.2	12.5	-16.7
25	4.2	62.5	0.0	33.3	+33.3
26	0.0	62.5	0.0	37.5	+37.5
27	0.0	70.8	8.3	20.8	+12.5
28	0.0	66.7	12.5	20.8	+ 8.3
29	4.2	62.5	8.3	25.0	+16.7
			Section IV-A		
30	45.8	29.2	8.3	16.7	+ 8.4
31	50.0	12.5	29.2	8.3	-20.9
32	62.5	8.3	16.7	12.5	- 4.2
			Section IV-B		
33	--	--	--	--	--
34	--	--	--	--	--
			Section IV-C		
35	--	--	--	--	--
36	--	--	--	--	--
37	--	--	--	--	--
38	--	--	--	--	--
39	--	--	--	--	--
40	--	--	--	--	--

Table 0. Total test evaluation for group 12a (17 Agronomy 1 students) from pretest to posttest using the Teaching Program.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	17.6	41.2	29.4	11.8	-17.6
2	88.2	0.0	5.9	5.9	0.0
3	11.8	35.3	35.3	17.6	-17.7
4	23.5	35.3	35.3	5.9	-29.4
5	11.8	58.8	17.6	11.8	- 5.8
6	52.9	0.0	5.9	41.2	+35.3
7	64.7	0.0	5.9	29.4	+23.5
8	64.7	11.8	11.8	11.8	0.0
9	94.2	5.9	0.0	0.0	0.0
10	17.6	35.3	29.4	17.6	-11.8
11	70.6	17.6	5.9	5.9	0.0
12	47.1	23.5	17.6	11.8	- 5.8
13	29.4	11.8	35.3	23.5	-11.8
14	35.3	23.5	29.4	11.8	-17.6
			Section II		
15	5.9	41.2	47.1	5.9	-41.2
16	5.9	35.3	5.9	52.9	+47.0
17	23.5	23.5	5.9	47.1	+41.2
18	35.3	23.5	23.5	17.6	- 5.9
19	23.5	17.6	35.3	23.5	-11.8
20	70.6	5.9	11.8	11.8	0.0
21	11.8	70.6	5.9	11.8	+ 5.9
			Section III		
22	23.5	5.9	11.8	58.8	+47.0
23	0.0	35.3	0.0	64.7	+64.7
24	23.5	0.0	5.9	70.6	+64.7
25	11.8	5.9	5.9	76.5	+70.6
26	0.0	94.2	0.0	5.9	+ 5.9
27	5.9	41.2	0.0	52.9	+52.9
28	5.9	29.4	0.0	64.7	+64.7
29	0.0	52.9	0.0	47.1	+47.1
			Section IV-A		
30	47.1	29.4	5.9	17.6	+11.7
31	64.7	17.6	5.9	11.8	+ 5.9
32	82.4	5.9	5.9	5.9	0.0
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	100.0	0.0	0.0	0.0
			Section IV-C		
35	--	--	--	--	--
36	--	--	--	--	--
37	--	--	--	--	--
38	--	--	--	--	--
39	--	--	--	--	--
40	--	--	--	--	--

Table P. Total test evaluation for group 13a (22 Agronomy 1 students) from pretest to posttest using the Teaching Program.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	13.6	54.5	18.2	13.6	- 4.6
2	72.7	0.0	13.6	13.6	0.0
3	18.2	63.6	13.6	4.6	- 9.0
4	18.2	40.9	31.8	9.1	-22.7
5	9.1	63.6	13.6	13.6	0.0
6	63.6	0.0	0.0	36.4	+36.4
7	50.0	0.0	13.6	36.4	+22.8
8	27.3	40.9	22.7	9.1	-13.6
9	95.5	0.0	0.0	4.6	+ 4.6
10	18.2	31.8	31.8	18.2	-13.6
11	22.7	27.3	18.2	31.8	+13.6
12	27.3	27.3	18.2	27.3	+ 9.1
13	63.6	9.1	0.0	27.3	+27.3
14	27.3	45.5	18.2	9.1	- 9.1
			Section II		
15	4.6	36.4	54.5	4.6	-49.9
16	0.0	36.4	4.6	59.1	+54.5
17	59.1	9.1	4.6	27.3	+22.7
18	31.8	13.6	18.2	36.4	+18.2
19	22.7	31.8	22.7	22.7	0.0
20	59.1	9.1	9.1	22.7	+13.6
21	9.1	54.5	18.2	18.2	0.0
			Section III		
22	27.3	22.7	4.6	45.5	+40.9
23	0.0	54.5	0.0	45.5	+45.5
24	18.2	9.1	4.6	68.2	+63.6
25	0.0	18.2	0.0	81.8	+81.8
26	0.0	90.9	0.0	9.1	+ 9.1
27	0.0	68.2	4.6	27.3	+22.7
28	4.6	50.0	4.6	40.9	+36.3
29	0.0	63.6	4.6	31.8	+27.2
			Section IV-A		
30	13.6	31.8	22.7	31.8	+ 9.1
31	54.5	0.0	22.7	22.7	0.0
32	63.6	4.6	18.2	13.6	- 4.6
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	100.0	0.0	0.0	0.0
			Section IV-C		
35	--	--	--	--	--
36	--	--	--	--	--
37	--	--	--	--	--
38	--	--	--	--	--
39	--	--	--	--	--
40	--	--	--	--	--

Table Q. Total test evaluation for group 14a (15 Soil Fertility students) from pretest to posttest using the Sanilac Report.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	40.0	26.7	20.0	13.3	- 6.7
2	80.0	6.7	6.7	6.7	0.0
3	13.3	46.7	26.7	13.3	-13.4
4	26.7	53.3	13.3	6.7	- 6.6
5	53.3	13.3	0.0	33.3	+33.3
6	53.3	6.7	13.3	26.7	+13.4
7	33.3	26.7	20.0	20.0	0.0
8	53.3	26.7	13.3	6.7	- 6.6
9	100.0	0.0	0.0	0.0	0.0
10	26.7	33.3	13.3	26.7	+13.4
11	73.3	0.0	6.7	20.0	+13.3
12	60.0	13.3	13.3	13.3	0.0
13	46.7	20.0	13.3	20.0	+ 6.7
14	33.3	40.0	13.3	13.3	0.0
			Section II		
15	40.0	20.0	26.7	13.3	-13.4
16	0.0	93.3	0.0	6.7	+ 6.7
17	6.7	40.0	13.3	40.0	+26.7
18	33.3	33.3	6.7	26.7	+20.0
19	46.7	20.0	0.0	33.3	+33.3
20	66.7	13.3	6.7	13.3	+ 6.6
21	60.0	6.7	0.0	33.3	+33.3
			Section III		
22	33.3	33.3	26.7	6.7	-20.0
23	0.0	100.0	0.0	0.0	0.0
24	6.7	66.7	6.7	20.0	+13.3
25	0.0	66.7	6.7	26.7	+20.0
26	0.0	100.0	0.0	0.0	0.0
27	0.0	93.3	0.0	6.7	+ 6.7
28	0.0	80.0	0.0	20.0	+20.0
29	13.3	53.3	6.7	26.7	+20.0
			Section IV-A		
30	46.7	13.3	33.3	6.7	-26.6
31	66.7	13.3	13.3	6.7	- 6.6
32	66.7	0.0	13.3	20.0	+ 6.7
			Section IV-B		
33	0.0	100.0	0.0	0.0	0.0
34	0.0	100.0	0.0	0.0	0.0
			Section IV-C		
35	0.0	100.0	0.0	0.0	0.0
36	0.0	80.0	20.0	0.0	-20.0
37	0.0	93.3	6.7	0.0	- 6.7
38	0.0	86.7	13.3	0.0	-13.3
39	0.0	86.7	13.3	0.0	-13.3
40	0.0	86.7	13.3	0.0	-13.3

Table R. Total test evaluation for group 14b (15 Soil Fertility students) from pretest to post-posttest using the Sanilac Report.

Item No.	Percent correct pre & post	Percent incorrect pre & post	Percent correct pre incorrect post	Percent incorrect pre correct post	Percent pre-post change
			Section I		
1	20.0	20.0	40.0	20.0	-20.0
2	60.0	6.7	26.7	6.7	-20.0
3	20.0	40.0	20.0	20.0	0.0
4	26.7	53.3	13.3	6.7	- 6.6
5	46.7	20.0	6.7	26.7	+20.0
6	66.7	0.0	0.0	33.3	+33.3
7	53.3	0.0	0.0	46.7	+46.7
8	53.3	20.0	13.3	13.3	0.0
9	93.3	0.0	6.7	0.0	- 6.7
10	20.0	26.7	20.0	33.3	+13.3
11	80.0	6.7	0.0	13.3	+13.3
12	46.7	13.3	26.7	13.3	-13.4
13	53.3	20.0	6.7	20.0	+13.3
14	33.3	33.3	13.3	20.0	+ 6.7
			Section II		
15	46.7	20.0	20.0	13.3	- 6.7
16	0.0	80.0	0.0	20.0	+20.0
17	13.3	46.7	6.7	33.3	+26.6
18	33.3	20.0	6.7	40.0	+33.3
19	33.3	20.0	13.3	33.3	+20.0
20	66.7	13.3	6.7	13.3	+ 6.6
21	60.0	6.7	0.0	33.3	+33.3
			Section III		
22	53.3	13.3	0.0	33.3	+33.3
23	0.0	93.3	0.0	6.7	+ 6.7
24	6.7	40.0	6.7	46.7	+40.0
25	6.7	13.3	0.0	80.0	+80.0
26	0.0	100.0	0.0	0.0	0.0
27	0.0	80.0	0.0	20.0	+20.0
28	0.0	86.7	0.0	13.3	+13.3
29	13.3	60.0	6.7	20.0	+13.3
			Section IV-A		
30	40.0	13.3	40.0	6.7	-33.3
31	60.0	13.3	20.0	6.7	-13.3
32	66.7	0.0	13.3	20.0	+ 6.7
			Section IV-B		
33	0.0	93.3	0.0	6.7	+ 6.7
34	0.0	93.3	0.0	6.7	+ 6.7
			Section IV-C		
35	0.0	100.0	0.0	0.0	0.0
36	0.0	80.0	20.0	0.0	-20.0
37	0.0	93.3	6.7	0.0	- 6.7
38	0.0	86.7	13.3	0.0	-13.3
39	0.0	86.7	13.3	0.0	-13.3
40	0.0	86.7	13.3	0.0	-13.3

APPENDIX B

AN EVALUATION OF COMPREHENSION OF SOIL SURVEY INFORMATION AND ITS INTERPRETATION

(52-item test)

DEVELOPMENT AND TESTING OF "AN EVALUATION OF COMPREHENSION OF SOIL SURVEY INFORMATION AND ITS INTERPRETATION" TEST, USED FOR PRETESTING AND POSTTESTING COUNTY AGRICULTURAL EXTENSION AGENTS

This evaluation test was carefully constructed to measure the following kinds of information: (1) a broad spectrum of soil survey and management information, (2) soil classification information necessary to understanding the implications of soil type name, mapping unit symbol, and management symbol, (3) identification of management group symbols, (4) kinds and arrangement of information in the different sections of the 1962 "Know Your Soils," and (5) definitions of important technical terms.

Initially two tests, 52 items each, were written consisting of similar information for each item, e.g. 'a soil series is a subdivision of a soil type' for test #1, and 'a soil series is a subdivision of a soil phase' for test #2.

It was planned to use one test as a pretest and the other as a posttest. These tests were administered to members of the Soil Science staff and graduate students to determine the range of item difficulties and to identify poorly worded or inaccurate questions. The tests were revised to remove any flaws detected during the testing.

Subsequently, these tests were submitted to Dr. John M. Parsey in Agricultural Communications Research for final review and counsel. Dr. Parsey suggested that only one test should be used for all testing as the error caused by two different tests is greater than error that could result from learning caused by repeated use of one test. Accordingly, the best item was selected from each pair of corresponding items on the two initial tests and used to construct the following 52 item evaluation test. It was used for pretesting and posttesting the county agricultural extension agents who participated in the county agent training seminar.

AN EVALUATION OF COMPREHENSION

OF

SOIL SURVEY INFORMATION AND ITS INTERPRETATION

Directions:

1. Indicate the time you start and time you finish.

NOTE: Results of your test will be kept confidential.

Your assistance and cooperation are of great value in this study and are sincerely appreciated.

Roger Pennock Jr.

Starting time: ______________ Completion time: _________

NAME ______________________________

DATE _______________

I. Circle (T) if true and (F) if false.

T F 1. The index map in a county soil survey report shows all the soils found in that county.

T F 2. "Reference numbers" are shown on the index map of a soil survey report.

T F 3. Local soil differences in Michigan are often caused by differences in the original vegetation.

T F 4. Glacial till is water-sorted material deposited by streams flowing away from a glacier.

T F 5. A soil series is a subdivision of a soil type.

T F 6. Soils in the management groups containing (a), such as the 3a group, are well drained.

T F 7. A soil in the 4c management group is coarser textured than one in the 3a group.

T F 8. Minimum tillage plowing can be done when the soil is too wet for conventional tillage.

T F 9. Dolomitic limestone will supply magnesium where it is needed by crops.

T F 10. Oats commonly respond to additions of manganese on soils containing free lime in the plow layer.

T F 11. The most protective rotation recommended is cited in the table for each of the soil management units.

T F 12. Two soils (A & B) have a sandy loam texture and a pH of 5.5 in the plow layer, but soil A has a darker colored surface than B. Soil A would require less lime than B.

T F 13. Descriptions of management groups in the white section give information about their readily available moisture holding capacity.

T F 14. Blinding should be used on tile laid in sandy materials.

T F 15. Organic soils are often deficient in potassium.

II. Check the correct response to each question or statement.

A. A Marlton loam soil had the following:

mapping unit symbol = MaB1, and

management unit symbol = 1bB (IIIW).

16. a) Texture of the surface soil is:

_________ sandy loam _________ clay loam

_________ loam _________ silty clay

17. b) Average texture of the profile is:

_________ sandy loam _________ clay loam

_________ loamy sand _________ silty clay

18. c) Natural drainage of the soil is:

_________ poorly drained _________ well drained

_________ imperfectly drained

19. d) The slope of this soil is:

_________ 0-2% _________ 6-12%

_________ 2-6% _________ 12-16%

20. e) The erosion class is:

_________ none _________ moderate

_________ slight _________ severe

21. f) Marlton is a:

_________ soil type _________ soil series

_________ soil phase _________ Great Soil Group

22. The most serious problem to crop production is:

_________ rooting zone limitation

_________ wetness

_________ erosion

_________ no limitation

III. Pick the proper management group symbol from the following list for each of the soil descriptions below:

1a 1b 1c 2a 2b 2c 3a 3b 3c 4a 4b 4c 5b(h)

5.7a 2/Ra 2/Rc 3/2a 3/2b 3/2c 4/Ra 4/Rc Ra Rc

L2a L2c Sa Sc Mc Mc-a

23. a) __________ A well drained clay soil.

24. b) __________ Lake marsh.

25. c) __________ Deep muck.

26. d) __________ A poorly drained soil with 30 inches of sandy loam over loam.

27. e) __________ A poorly drained soil with 11 inches of sand over bedrock.

28. f) __________ An imperfectly drained loamy sand soil.

29. g) __________ A poorly drained loam textured Alluvial soil.

30. h) __________ A soil whose subsoil is cemented with iron oxide.

IV-A. Included in the <u>yellow section</u> of "Know Your Soils" is a discussion of general principles of profitable soil management. Place a check (✓) before each of the following statements that is a major topic in this section and an (X) for each one that is not.

31. a) __________ conventional tillage

32. b) __________ correction of soil acidity

33. c) __________ fertilizer recommendations and interpretation of soil tests

34. d) __________ drainage recommendations

35. e) __________ fertilization of organic soils

36. f) __________ fertilizer placements

IV-B. The <u>white section</u> (pp. 13-35) deals with properties of soil management groups and recommendations for their management.

A) Re-arrange the following list of management groups in the sequence that they occur from beginning to end of this section of "Know Your Soils."

L   1a   Oa   4b   3c

37. __________

38. __________

39. __________

40. __________

41. __________

IV-C B) Place a check (✓) before each of the following statements that is a major topic in this section and an (X) for each that is not.

42. a) __________ Micronutrients

43. b) __________ Description (of management groups)

44. c) __________ Cropping systems and erosion control practices

45. d) __________ Average crop yields expected with recommended management

46. e) __________ The effect of different parent materials on soil characteristics

47. f) __________ How slope length is determined

V. Give a clear concise definition of each of the following words or terms:

48. a) Slope class (define and give an example)

49. b) Lowlands

50. c) 3/2a management group

51. d) Micronutrient

52. e) Relative protectiveness

APPENDIX C

SUGGESTIONS ON FEATURES THAT MAY INCREASE THE USEABILITY, OR EASE OF USE, OF SOIL SURVEY REPORTS THAT HAVE RESULTED FROM EXPERIENCES WITH USE OF RECENTLY PUBLISHED REPORTS IN MICHIGAN (LENAWEE, AND SANILAC COUNTIES)

SUGGESTIONS ON FEATURES THAT MAY INCREASE THE USEABILITY, OR EASE OF USE, OF SOIL SURVEY REPORTS THAT HAVE RESULTED FROM EXPERIENCES WITH USE OF RECENTLY PUBLISHED REPORTS IN MICHIGAN (LENAWEE, AND SANILAC COUNTIES)

(These suggestions accompanied a letter addressed to Mr. Clarence Engberg, State Soil Scientist, Soil Conservation Service, East Lansing, Michigan, on March 27, 1964.)

I. Index to Map Sheets

A. Show political township boundaries and names as in the revised index map for southern Sanilac County attached.

B. Give section numbers of all sections as in the revised index map of southern Sanilac County.

C. Exaggerate (or accentuate) survey township boundaries, particularly on the border of the map. (See example on attached revised index map for southern Sanilac County).

D. Indicate the map chart number and boundaries with transparent colored inks. (See example of yellow on attached revised index map of southern Sanilac County).

E. If possible, include road names on the index maps.

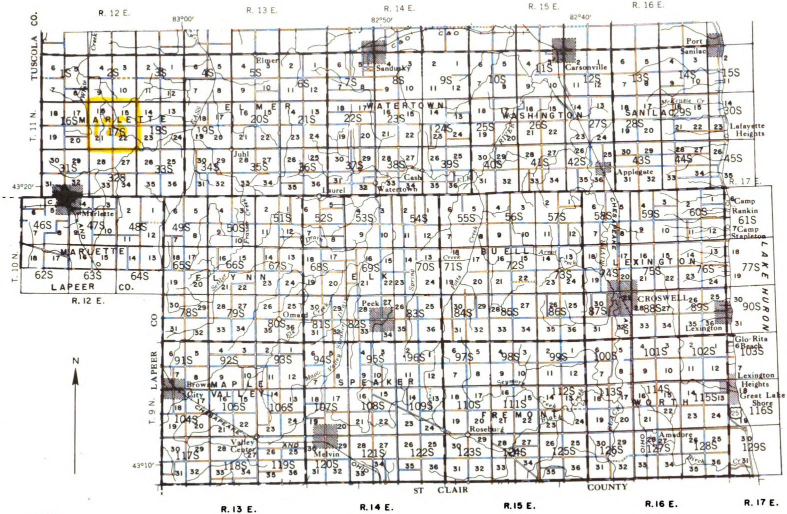
F. Include all public roads on the Index to Map Sheets. Absence of some roads on the Montcalm and Lenawee County Soil Survey Report index maps have handicapped their use by farmers. It is largely for this reason that we have based our comments above on the Sanilac County Soil Survey Report index map. We trust that the desirable features of it will be continued along with consideration of the above suggested revisions shown for southern Sanilac County and mentioned in E above.

INDEX TO MAP SHEETS

SANILAC COUNTY, MICHIGAN

Scale

1 0 1 2 3 4 5 Miles



O-3477

II. Map Sheets With Air Photo Bases

A. Increase sharpness and contrast of the air photo background where possible.

B. Place photo sheet numbers in upper righthand corner of the sheets as they will appear after folding and binding in the report. Commonly, the numbers on folded map sheets are hidden near the bound edge of the report instead of appearing on the outer edge where they can be seen in thumbing through the pages. The number of the inside of the folded sheet and the outside of the folded sheet might be given, preceded by Inside and Outside, respectively.

C. Unfolded sheets as in Sanilac County avoid the preceding criticism, are more convenient to use than the foldout sheets, and do not wear out on the fold. Since the boundaries between the map sheets on the Sanilac County index map do not cross township lines, the sheets and farms are easier to locate from their legal descriptions. The larger scale is also an advantage.

III. The Guide to Mapping Units in the back of the Lenawee County Report could well serve as the soils legend for use with the maps. It has the great advantage of leading the user into the text where the soils are described and their management discussed. These cross-references to the text in the guide are very helpful.

IV. A cross reference from the legend of the soil association map to the text would also be very desirable.

APPENDIX D

RECOMMENDATIONS TO THE MICHIGAN STATE SOIL TESTING LABORATORY IN REGARD TO MORE EFFECTIVE USE OF SOILS INFORMATION

Recommendations to the Michigan State Soil Testing Laboratory in Regard to More Effective Use of Soils Information

I. Punch date on IBM card. This will make it possible to sequence cards chronologically and therefore check them against white sheets if ever necessary.

II. Include the following information about soils on IBM cards.

A. Soil management group
  1. Profile texture
  2. Drainage

B. Soil surface texture.

C. Special symbols (L = alluvial, a = acid, h = humus pan).

D. Use a 5 digit number for soil management "subgroup."
  1. First two digits (one and two) for soil management group texture, i.e. 1.0, 1.5, 2.0, 2.5, 3.0 . . . or 4/2, 3/2, 4/1, or L, m, R (2nd digit) i.e 1L
  2. Third digit for drainage class, i.e. a, b, c
  3. Fourth for special (f = fragipan, h = humus pan, a = acid)
  4. Fifth digit for surface texture, i.e.
     1 = sand and fine sand
     2 = loamy sands
     3 = sandy loams (except, very fine sandy loam)
     4 = loam
     5 = silt loam and very fine sandy loam
     6 = clay loam
     7 = silty clay loam
     8 = silty clay
     9 = clay

     example: 5.3a-h with sand surface <u>5</u> <u>3</u> <u>a(1)</u> <u>h(2)</u> <u>1</u>

     or: L4a with sand surface <u>4</u> <u>L(6)</u> <u>a(1)</u> <u>1</u>

III. If soil type number is given, it will be punched in card as follows:

A. First col. (use * or other symbol or leave blank to indicate that the subsequent numbers represent soil type and not soil management subgroups).

B. Cols. 2, 3, 4, and 5 (punch in soil type number). A state-wide soil type numbering system is available for research purposes.

IV. Dark colored soils indicated by a punch in col. 4 in row #1 position.

V. Sources of information.

A. Soil type from modern soil survey (4 digits in cols. 2, 3, 4, 5).
   1. Surface color as 4 in col. 4.
   2. Can this type no. be converted and printed out as a management subgroup by the IBM machine?

B. Soil management group sent with sample.
   1. Punch in the management group symbol.
   2. Determine surface texture by hand texturing each sample in the lab.
   3. Determine whether sample is light or dark by use of Munsell color chart in the lab.

      a. 10YR3/1 or 10YR2/2 or darker are dark colored soil; 10YR3/2 is borderline between light and dark; others are light colored soils.

C. No information sent with sample.
   1. Hand texture sample in lab. and punch surface texture in col. 5.
   2. Determine color with Munsell chart and indicate dark colored as mentioned before, as 4 in col. 4.

VI. Methods of recording information.

A. Cols. 1, 2 (management group textures)

0.__	= clay (> 55% clay)	2/R	= l-sl/bedrock
1.__	= clay & silty clay	3/1	= sl/sic-c
1.5	= clay loam & silty clay loams	3/2	= sl/cl-l
2.__	= clay loams & loams	4/1	= ls-s/c-sic
2.5	= loam & silt loam	4/2	= ls-s/cl-l
3.__	= sandy loams	4/R	= ls-s/bedrock
4.__	= loamy sands	5/2	= s/l-c, at 40-65 inches
5.0	= sands		
5.3	= sands very droughty		
5.7	= sands extremely droughty		

g__ = gravelly, cobbly, stony (col. 1, row 6)

L = alluvial (col. 2, row 6)

M__ = organic (deep) (col. 1, row 8)

M/1 = organic /c-sic

M/3 = organic /sl-sicl

M/4 = organic /ls-s

M/m = organic /marl

R__ = < 18" to bedrock (col. 1, row 9)

S__ = lake, beach or marsh (col. 1, row 7)

B. Col. 3 (management group drainage).

i.e. a = good and moderately good drainage
b = imperfect or somewhat poor drainage
c = poor and very poor drainage

C. Col. 4 (special symbols).

i.e. a = extremely acid soils and peats
h = humus pan
f = fragipan
d = dark colored

D. Col. 5 (texture of the topsoil).

i.e. 1 = sand
2 = loamy sand
3 = sandy loam
4 = loam
5 = silt loam
6 = clay loam
7 = silty clay loam
8 = silty clay
9 = clay

E. (Dark colored soils).

1. Punch in col. 4 in row 4 position.

IBM CODING EXAMPLE

Management group no. col. 1	row	col. 2	row	Drainage col. 3	row	Subgroup col. 4	row	Surface texture col. 5	row
0	0	--	--						
1	1	--	--	a	1	a = very acid	1	clay	9
1	1	.5	5	b	2	h = humus pan	2	sic	8
2	2	--	--	c	3	f = fragipan	3	sicl	7
2	2	.5	5			d = dark color surface	4	cl	6
2	2	/R	9					sil	5
3	3	--	--					loam	4
3	3	/1	1					sl	3
3	3	/2	2					ls	2
4	4	--	--					sand	1
4	4	/1	1						
4	4	/2	2						
4	4	/R	9						
5	5	--	--						
5	5	/2	2						
5	5	.3	3						
5	5	.7	7						
g	6	--	--						
S	7	--	--						
M	8	--	--						
M	8	/1	1						
M	8	/3	3						
M	8	/4	4						
M	8	/m	8						
R	9	--	--						
2	2	L	6						
4	4	L	6						

APPENDIX E

AN EVALUATION OF COMPREHENSION OF SOIL SURVEY INFORMATION AND ITS INTERPRETATION

(40-item test)

AN EVALUATION OF COMPREHENSION

OF

SOIL SURVEY INFORMATION AND ITS INTERPRETATION

Directions:

1. Indicate the time you start and time you finish.

NOTE: Results of your test will be kept confidential.

Your assistance and cooperation are of great value in this study and are sincerely appreciated.

Roger Pennock Jr.

Starting time: __________ Completion time: ________

Name ______________________________

Date ______________________________

I. Circle (T) if true and (F) if false.

T F 1. The index map in a county soil survey report shows all the soils found in that county.

T F 2. "Reference numbers" are shown on the index map of a soil survey report.

T F 3. Local soil differences in Michigan are often caused by differences in the original vegetation.

T F 4. Glacial till is water-sorted material deposited by streams flowing away from a glacier.

T F 5. A soil series is a subdivision of a soil type.

T F 6. Soils in the management groups containing (a), such as the 3a group, are well drained.

T F 7. A soil in the 4c management group is coarser textured than one in the 3a group.

T F 8. Minimum tillage plowing can be done when the soil is too wet for conventional tillage.

T F 9. Dolomitic limestone will supply magnesium where it is needed by crops.

T F 10. Oats commonly respond to additions of manganese on soils containing free lime in the plow layer.

T F 11. Two soils (A & B) have a sandy loam texture and a pH of 5.5 in the plow layer, but soil A has a darker colored surface than B. Soil A would require less lime than B.

T F 12. Descriptions of management groups in the white section give information about their readily available moisture holding capacity.

T F 13. Blinding should be used on tile laid in sandy materials.

T F 14. Organic soils are often deficient in potassium.

II. Check the correct response to each question or statement.

A Marlton loam soil had the following:

mapping unit symbol = MaB1, and
management unit symbol = 1bB (IIIW)

15. Texture of the surface soil is:

__________ sandy loam　　__________ clay loam

__________ loam　　__________ silty clay

16. Average texture of the profile is:

__________ sandy loam　　__________ clay loam

__________ loamy sand　　__________ silty clay

17. Natural drainage of the soil is:

__________ poorly drained　　__________ well drained

__________ imperfectly drained

18. The slope of this soil is:

__________ 0-2%　　__________ 6-12%

__________ 2-6%　　__________ 12-16%

19. The erosion class is:

__________ none　　__________ moderate

__________ slight　　__________ severe

20. Marlton is a:

__________ soil type　　__________ soil series

__________ soil phase　　__________ Great Soil Group

21. The most serious problem to crop production is:

__________ rooting zone limitation

__________ wetness

__________ erosion

__________ no limitation

III. Pick the proper management group symbol from the following list for each of the soil descriptions below:

1a 1b 1c 2a 2b 2c 3a 3b 3c 4a 4b 4c

5b(h) 5.7a 2/Ra 2/Rc 3/2a 3/2b 3/2c 4/Ra 4/Rc

Ra Rc L2a L2c Sa Sc Mc Mc-a

22. ____________ A well drained clay soil.

23. ____________ Lake marsh.

24. ____________ Deep muck

25. ____________ A poorly drained soil with 30 inches of sandy loam over loam.

26. ____________ A poorly drained soil with 11 inches of sand over bedrock.

27. ____________ An imperfectly drained loamy sand soil.

28. ____________ A poorly drained loam textured Alluvial soil.

29. ____________ A soil whose subsoil is cemented with iron oxide.

IV. Fill in the blanks with the appropriate information.

A. Place 1 before the soil needing the least lime,
Place 2 before the soil needing more lime,
Place 3 before the soil needing the most lime.

30. ____________ silt loam soil plowed 8 inches deep.

31. ____________ sandy loam soil plowed 6 2/3 inches deep.

32. ____________ sandy loam soil plowed 8 inches deep.

B. According to the state soil test lab. phosphorus is low if

33. the test shows less than __________ and potassium is low if it

34. tests less than __________ for a crop of corn.

C. List 3 of the 7 factors included in the universal soil loss equation. Give the letter and its meaning, (for each).

35. ____________ 36. ____

37. ____________ 38. ____

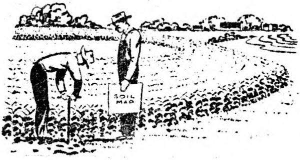
39. ____________ 40. ____

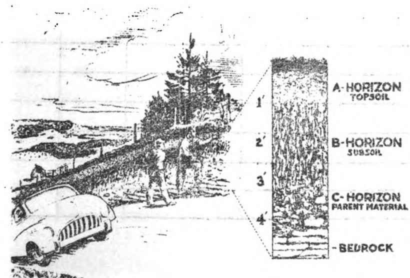
APPENDIX F

1962 "KNOW YOUR SOILS"

KNOW YOUR SOILS
AND HOW TO USE THEM

"...RETAINING THE MAXIMUM FERTILITY OF THEIR SOIL. THERE IS NO SUBJECT TO OUR PEOPLE OF PROFOUNDER CONCERN, OR OF MORE FAR REACHING IMPORTANCE." J. S. MORRILL





Prepared by
SOIL SCIENCE DEPARTMENT
MICHIGAN STATE UNIVERSITY
and
SOIL CONSERVATION SERVICE
U.S. DEPT. OF AGRICULTURE

1962

HOW THIS CIRCULAR IS TO BE USED:

If you are interested in the general nature of the soils of your county and how their properties are important to their use for various purposes, you will find these matters discussed in the yellow section of this report.

If you are interested in the soils on a particular area in your county:

1. Locate the area on the index map. A copy is available through the Cooperative Extension Service or the Soil Conservation Service. The towns, township names, (or township and range numbers), section numbers, roads, railroads and streams should assist in this process. On the index map you will find the reference number for the soil map of your area.
2. Outline the boundaries of your farm on the soil map. A recent county plat book will help you locate the tract. School houses and farm homes are also shown on the soil map. Be sure to note any differences in the scales of the index and soil maps and which direction is north!
3. List the mapping units shown on your farm in the first column of table 1.
4. Copy the names of the mapping units and the soil management group designation of each into column 2 and 3 of table 1 from the list of soil types.
5. Brief descriptions of these soil management groups and suggestions on their management, and their productivity for various crops when well managed, are given for each management group in numerical and/or alphabetical order in the white section in the back of this circular. For example, the 2a, 2b groups will be found immediately after the 1a, 1b, 1c groups and the 2c group will follow the 2a, 2b groups. The group designations beginning with a letter follow those beginning with numbers. Thus, the L and M groups follow the groups designated 5/2a, 5/2b, Ga and Gc. Compare these descriptions and the accompanying information with what you know about the soils on your farm and how you are managing each!
6. Outline changes in the use or management of your soils that would be likely to increase the net economic returns from your land or otherwise increase your satisfaction from its wise utilization. Plan to incorporate these changes in your management plans for each field. Repeating steps 3, 4, and 5 for individual fields will help you do this.
7. If further information is needed, consult the local Cooperative Extension Service or Soil Conservation Service representative.

Table 1. Soils on my farm.

Mapping unit symbol	Soil name	Soil management unit		
		Soil management group	Slope class	Erosion class

HOW TO MAKE THE BEST USE OF YOUR SOILS

Are you taking full advantage of all the useful information available about the kinds of soils in your county? In addition to its usefulness in soil management, such information can be helpful in:

1) land evaluation for various purposes, such as security for loans, purchase or sale values, or assessments of various kinds;
2) determining suitability for urban, industrial, agricultural or constructional uses;
3) the design of roads, drainage systems, irrigation systems, sewage disposal systems or foundations for buildings;
4) location of sites suitable for expanding business ventures such as production of foods or fibres, or establishment of plants suitable for their processing and marketing.

Information on availability of soil maps for this county are available at either the county office of the Cooperative Extension Service or the Soil Conservation Service.

This publication summarizes some of the useful information about soils in your county. Knowledge of what these soils are and where each kind is found is the result of cooperative studies by the U. S. Department of Agriculture, the Michigan Agricultural Experiment Station and other cooperating agencies over the past 60 years. How this information is gathered and how the soil maps are made is discussed on the back cover of this circular. The ideas concerning the utilization, management, and productivity of these soils are based upon research and the experiences of users of similar soils.

The first part of this circular discusses how the soils differ from each other, how they can be grouped for management purposes and how their differences are important in their utilization. The following pages give information on: the properties of each soil management group, its management problems, the crops adapted to each, suitable crop rotations, conservation practices for controlling erosion and maintaining yields, drainage requirements, and fertilizer recommendations.

The expected average crop yields when the recommended management practices are followed for each soil management group and its subdivision into slope or eroded phases are also listed. These phases of the soil management groups are called soil management units or land capability units. Directions for the use of this more detailed information about soil management groups are given inside the front cover of this circular.

How and why do the soils in this area differ from one another? In plowing a field, one notes in the overturned furrow slice various shades of color ranging all of the way from deep black to light grey or yellow. To the soil scientist, these shadings of yellow, grey and black and the sandy to clayey texture mean types of soil that have distinct origins and certain basic characteristics. Each kind of soil needs certain types of treatment to get the most return from that soil. If you were to take a huge axe or hoe and slice down through the soil on one of the fields and lift out a section, like one would a piece of layer cake, the vertical side of this piece of soil cake would also show layers that differ in color and texture. This is called the soil profile. Some soils common to East Central Michigan are shown in Figure 1.

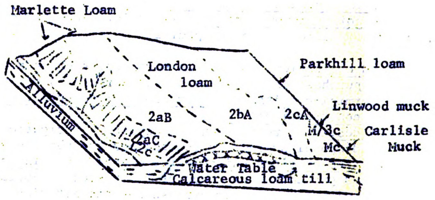


Fig. 1. The letters and numbers of this diagram show the soil management units to which each belongs.

The difference in these soils are mainly associated with differences in: (1) their age, (2) texture of the parent materials from which they were formed, and (3) in natural drainage within the area.

Alluvial soils on the lowlands (L) or overflow lands, are still receiving sediments from flood waters. The properties, however, are largely those of the original sediments. Some differences in past drainage are evident in their color and organic content.

Organic or muck soils (M), are found in the most poorly drained upland areas. In these soils, organic matter has accumulated over the original mineral deposits. Where this organic layer is one foot or more thick they are called Organic soils.

What are the soils in your county? The soils in this county are listed with the mapping unit symbols among the information available from the Cooperative Extension Service or the Soil Conservation Service for your area. The soil series names are arranged in the key accompanying the list of mapping units: vertically, according to the texture or the parent materials from those that were formed, from the finest textures at the top of the table (clays) to the coarsest textures at the bottom (sands), and horizontally, on each line are the soils formed from similar kinds of parent materials. Those developed under the best natural drainage conditions (well-drained) are shown at the left and those formed under the poorest natural drainage (poorly or very poorly drained) at the right of the key. In some cases these soils have formed in layers of more than one kind of material. Thus, thin organic soils may form in the most poorly drained sites over mineral materials within 12 to 42 inches of the surface. The young Alluvial soils found on lowlands (L) along streams are shown near the bottom of the key. All of these soils differ from each other in one or more ways that may be important for one or more uses. These differences are described in detailed county soil survey reports.

How may soils be grouped for management purposes? With our present knowledge, the soils that have profiles of similar texture or similar materials, similar natural drainage conditions, and similar age, may be grouped together for many management purposes. This grouping places together soil series with similar profile characteristics, similar management requirements and similar productivities when managed similarly. In table 2, these soil management groups are arranged in the same pattern as the soil series in the key discussed above.

Table 2. Relationships of soil management groups with connotative symbols.

Average texture of soil material or profile in mineral soils and character of organic materials	MINERAL SOILS			ORGANIC SOILS	
	Drainage (natural)			Very poorly drained	
	Good a	Imperfect b	Poor to very poorly c	Shallow, 12-42" thick c	Deep, 42" thick c
UPLANDS:					
Clay or silty clay, 1	1a	1b	1c	M/1c	
Clay loams or loam, 2	2a	2b	2c		
Loam to sandy loam, over bedrock at 18-42", 2/R	2/Ra	2/Rc	2/Rc		Mc
Sandy loam, 3	3a	3b	3c		
Sandy loam over clay to silty clay at 14-42", 3/1	3/2a	3/1b	3/1c	M/3c	
Sandy loam over clay loams to loam at 18-42", 3/2	3/2a	3/2b	3/2c		
Loamy sand to sand over clay to silty clay at 18-42", 4/1	4/2a	4/1b	4/1c		or
Loamy sand to sand over clay loam to loam at 18-42", 4/2	4/2a	4/2b	4/2c		
Sand to loamy sand, 4	4a	4b	4c		
Loamy sands to sands over bedrock at 18-42", 4/R	4/Ra	4/Rb	4/Rc	M/4c	
Sands, drouthy, 5	5a	5b	5c	or	Mc-a[2]
very drouthy, 5.3	5.3a, 5a(h)[1]	5b(h)[1]		Mc-a[2]	
extremely drouthy, 5.7	5.7a				
Sands over loam to clay at 42-66", 5/2	5/2a	5/2b	5c		
Stony, cobbly or gravelly, G	Ga	Gc	Gc		
Bedrock at<18", R	Ra	Rc	Rc		
ALLUVIAL SOILS, LOWLANDS, L:					
Moderately fine to moderately coarse textured	L2a	L2c	L2c		
Coarse textured	L4a	L4c	L4c		
MUCKS OR PEATS, over marl, M/m:			M/mc	M/mc	Mc
0-12 inches of muck over marl					
Lake beach, bluffs or dunes	Sa				
Lake marsh and wet swales			Sc		

1. Subsoil cemented with humus and iron oxides.
2. Formed in extremely acid woody and fibrous or fibrous organic materials.

The naturally well drained and moderately well drained mineral soils have been grouped together in column 'a' toward the left side of table 2 and the poorly to very poorly drained mineral and organic soils are shown at the right side of that table under the columns headed 'c'. The imperfectly drained mineral soils are in between under the column heading 'b'. The very poorly drained organic soils are designated with a capital "M", for mucks or peats. The relationships of some of these soils to one another in a landscape are shown in Figure 1.

Vertically within each of the columns mentioned in table 2, the soils formed in parent materials of similar textures or having similar textures of profiles are grouped together as indicated in the left-hand column. The finest-textured materials are shown at the top, 'clays and silty clays,' accompanied by the number 1. The successively coarser materials are listed lower in the table with the sands as number '5' at the bottom. The Alluvial soils on lowlands, L, are near the bottom of the table.

Each block in table 2 contains a combination of numbers and letters designating that particular soil management group. These designations tell us a good deal about the properties of the soils in each of those groups and their relationships to one another. For example, in the upper left-hand block, 1a, the soils have fine textured, clay profiles and are found in naturally well drained conditions on convex slopes with deep water tables. Their surfaces are lighter in color and their subsoils are brighter in color than the poorly drained soils. The poorly drained mineral soils in the block near the upper right-hand corner, 1c, also have fine textured profiles but they have darker colored surfaces and grayer subsoils because they were developed under naturally poorly or very poorly drained conditions. The shallow organic soils over the clay materials are shown as M/1c which tells us they are composed of muck or peat (M) 12 to 42 inches thick over clay (1) materials and were developed under naturally very poorly drained conditions (c). Where the organic materials are more than 42 inches thick, the soils are shown as Mc soils -- that is, deep organic soils (M) which were formed in conditions of very poor natural drainage (c).

How are the properties of these soils important in their use? The soils in the 'c' groups and most of those in the 'b' groups needed artificial drainage before they could be used successfully for most crops. The soils in the 'a' groups do not need artificial drainage but they are subject to water erosion, particularly on the steeper slopes. The 5a group of soils near the lower left part of table 2 are well drained or moderately well drained (a) soils formed from sands (5). These drouthy coarse-textured soils may be subject to water erosion on slopes but in cultivated areas they are subject to wind erosion even on level areas. Much of the precipitation will be lost by runoff from the well-drained clayey 1a soils, but it will enter streams from the well-drained sandy areas by movement through the soil.

Variations in slopes or degrees of erosion within the better drained soil groups are indicated by adding a capital letter (such as A=0-2%, B=2-6%, C=6-12%, D=12-18%, E=18-25%, F =25%) to indicate the slope class and a final number for the eroded class, 2=moderately eroded or 3=severely eroded. These map symbols are explained in the legend for the more detailed soils maps that are and may be available for your county. Since water runs off more rapidly on the steep slopes, these soils are more subject to erosion losses and more protective cropping rotations or conservation practices are needed to prevent excessive erosion. These subdivisions of the soil management groups are called soil management units or land capability units.

Within the soil management groups are also Alluvial soils on lowland areas along streams that are subject to seasonal flooding. As a result, these are not suitable sites for home construction and crop production is uncertain. These groups of soils are indicated by a capital letter "L" preceding the profile texture and drainage designations. For example, soils in the L2c group are poorly to imperfectly drained (c), moderately coarse to moderately fine textured (2), lowlands (L) subject to flooding.

Thus, the designations for these soil management groups and their subdivisions enable us to recall much useful information about these soils. They also indicate their relationships to each other in the properties of their profiles and their situation in the landscape.

Further discussion of the important differences among the soil management groups as to their available water-holding capacities, infiltration rates, permeabilities, and runoff, erosion, or leaching losses will be found in Special Bulletin 402, Soils of Michigan, of the Michigan Agricultural Experiment Station.

<u>How can these groups of soils be best used for crop production?</u> Specific recommendations for the use of each soil management group are given later in the white section of this circular. But, certain general principles of profitable soil management that apply to all these groups will be discussed here. These principles cover minimum tillage, weed control, correction of soil acidity, micronutrients, choice of adapted cropping systems, good seed - applied at proper rates, fertilizer requirements and placement, and other conservation practices.

Profitable farming requires a gross return from the sales of produce that exceeds the costs of production. A higher net return may result from increasing the amount produced per unit of expenditure or decreasing the costs per unit of production. <u>Minimum tillage</u> is the least tillage or seedbed preparation necessary to insure rapid seed germination, a good stand, and good crop yields. This practice decreases production costs to a minimum without decreasing production. It can result in savings of $3.00 to $7.00 per acre and valuable time during spring work. Ideally it should be a once-over operation and should leave the soil as porous as possible so that water and air can penetrate and provide good soil tilth. This management practice commonly results in less runoff, less erosion, more water storage for the crop, less weed growth early in the season, and better pest control. <u>For all crops, minimum tillage involves delay of plowing</u> until the soil is in good condition-not too wet, and adjusting the plow to to turn a good clean furrow with no trash showing. <u>A fitting tool</u> that has a slight leveling and firming action should be trailed behind the plow except on sand, loamy sand, or sandy loam soil groups. A section of a harrow, a rotary hoe, a cultipacker, or a plow packer are all good. <u>The remaining tillage operations vary somewhat with the crops as follows</u>:

<u>Corn</u> should be planted the day the field is plowed. The planter may be trailed in the tractor wheel marks if a narrow-guage tractor is available; otherwise, weight the planter or the press wheels to give contact of the seed with the surrounding soil. On sloping land, plant across the slope.

<u>Spring grain</u> should be planted the day the field is plowed. It is sometimes desirable to fill in the tractor wheel marks in front of the drill. For this purpose, a spike tooth dragged below the tongue of the drill is satisfactory. Some people have put dual wheels on the grain drill to add supporting surface. If the drill is not equipped with press wheels, pull a roller or cultipacker behind the drill.

Sugar beets should be planted with the beet drill the same day the field is plowed.

Potatoes may require other tillage methods and chemicals to controll quack grass and other weeds.

Beans should be planted before the soil becomes too dry. If weeds have sprouted after plowing, drag once and plant without further tillage.

Consider the suggestions under spring grains for adapting the drill to loose seedbeds. Perhaps as experience increases, the minimum tillage operations can be made more specific for the different soil management groups. To date, it has been successful in experiments on clay loams and coarser soil groups. On the fine textured soils, fall plowing is commonly practiced to advantage. A more complete discussion of results with minimum tillage with some excellent illustrations of equipment now in use will be found in Extension Bulletin 352.

Weed control may be easier with minimum tillage and chemical weed control practices can eliminate expensive cultivations. Weeds can restrict crop yields because they compete for nutrients, water and sunlight.

Correction of soil acidity is necessary for good growth of alfalfa and clovers on many of the well drained and imperfectly drained soils. The supply of available calcium or magnesium may be limiting for some other crops on some very acid soils. Both can be supplied with dolomitic limestone. Commonly, lime increases the availability of other nutrients such as phosphorus or decreases the toxic affects of elements such as aluminum or manganese on very acid soils. An increased supply of available nitrogen and better soil structure may also result from use of lime on acid soils. Very few of the poorly drained mineral soils in Michigan require lime and many soils contain too much lime! Test -- don't guess. Since some soils commonly do not need lime, the soil map can be useful in sampling a field to learn how much lime or fertilizer is needed. Take a composite sample of each kind of soil present in each field as suggested in Extension Folder F-278, How to Take Accurate Soil Samples. Sample separately the soils with different surface textures in each soil management group. It is not necessary to test soils containing free lime -- their pH's will commonly be above 8.0.

In general, the amount of lime needed to correct the acidity of a soil is dependent on the pH of the plow layer and its texture. The tons of agricultural lime needed at a given pH for soils of different surface textures are shown in table 3. The texture of the plow layer of the soil is given as a part of the soil type name in the list of soil mapping units. This may vary considerably from the overall texture of the soil profile on which the soil management groups are based.

Lime should be applied and worked into the plow layer preferably a year before an alfalfa or clover seeding. When more than 2 tons of lime are to be applied per acre, it is best to apply one half before plowing, disc it in and plow before applying the remaining lime. A complete discussion of lime for Michigan soils will be found in Extension Folder F-279.

Table 3. Tons of lime required to correct the acidity of the plow layer of soils with different pH's and textures.*

Plow layer or surface textures	Acidity and pH ranges			
	Slightly acid pH 6.4-6.0	Medium acid pH 5.9-5.5	Strongly acid pH 5.4-5.0	Very strongly acid pH 4.9-4.5
Sands and loamy sands**	1-1½ T.	1½-2½ T.	2½-3½ T.	3½-4½ T.
Sandy loams, loams,** and silt loams	1½-2½ T.	2½-3½ T.	3½-4½ T.	4½-5½ T.
Clay loams and clays	1½-2½ T.	3½-4½ T.	4½-5½ T.	5½-6½ T.
Mucks or peats	none	none	(needed only for celery, 3 T.)	2-5 T.

**If the plow layer is high in organic matter, as indicated by a dark color, these rates of application should be increased 50%.

* The buffer method for lime requirements now being used by the State Soil Testing Laboratory gives more precise measurements.

Micronutrients. Many soils in east central Michigan, such as the Wisner and Essexville series, contain free lime in the plow layer. This excess lime in the soil makes some elements insoluble and unavailable to some plants. Thus, oats commonly respond to manganese mixed with fertilizer applied at planting time. Wheat and barley may respond to manganese but not as frequently as oats. Sugar beets often need boron and manganese if grown on soils with a pH above 6.5. Beans and soybeans may need manganese on limy soils. Corn and beans occasionally respond to zinc on these soils.

Choice of adapted cropping systems. The rotation or cropping system used on a given field or farm should be adapted to the kinds of soils, and with proper management and associated conservation practices, should adequately protect them from loss in productivity and excessive erosion. The relative protectiveness of different crop sequences are shown in table 4. They are listed with the least protective, a continuous row crop (R) at the top and the most protective, a continuous sod crop such as a meadow, legume-grass mixture (M) at the bottom. The numbers opposite each cropping system indicate their relative protectiveness.

Erosion control. The suggested cropping systems for the various soil management groups on different slopes with given conservation practices are given in tables in the next section of this circular. The least protective rotation recommended is given there for each of the soil management units. This rotation or any more protective rotation in table 4 will adequately protect that management unit. All the crops in the rotation should be adapted to the particular soil in question as listed for the particular soil management group. The relative protectiveness of these cropping sequences vary with the associated fertilization, tillage, and crop residue management. The variations in recommended width of row and grain crop strips where strip cropping is used to control water or wind erosion are given in table [illegible]

Table 4. Cropping systems and their relative protectiveness[1]

Cropping system*	Relative protectiveness	Cropping system	Relative protectiveness
R.	20	MRO	78
RgmR	28	MROW	79
Rgm.	36	MMRgmRO	79
RRO.	39	MROgmW.	80
RRW.	42	MMRgmRW	80
RWRRO.	44	MMMRRO.	80
RO	48	MRW	81
RgmROgm.	50	MMWRO	82
RW	53	MMWgmRO	84
RgmRWgm.	53	MMROW	85
RWgmRgmROgm.	55	MMRO.	86
ROgm	57	MMROgmW	86
RWgm	61	MMRW.	87
MRORO.	66	MMMROW.	88
MRORW.	68	MWO	88
MRROW.	69	MMMRO	88
MROgmRO.	69	MMMRW	90
MRWRW.	70	MMMMRO.	91
MROgmRW.	71	MMMMRW.	91
MRWgmRW.	72	MMWO.	92
MRgmROgmW.	72	MO.	92
MMRORO	73	MMOW.	93
MMRORW	75	MMMWO	93
MMROgmRO	76	MW.	94
MMRRO.	77	MMO	96
MMRROW	77	MMW	97
MMROgmRW	77	MM(fc)O	98
MMRRW.	78	MM(fc)W	98
MMRWgmRW	78	M	99

[1] Values in this table assume that residues are returned and conventional tillage is used. To find other suitable rotations, locate the one recommended in the alphabetical list. Any rotation with a higher numerical relative protectiveness is also suitable.

*M = meadow; gm = green manure or winter cover; O = spring grain; R = row crop; W = winter grain; (fc) = field cultivator used.

Table 5. Variations in width of row crop or grain strips and maximum length of slopes where strip cropping is recommended for control of water erosion* on slopes of different gradients.

Slope class	Percent slope	Strip width (approx.)	Maximum length**
B	2.1 - 6.0	100-88 ft.	400 ft.
C	6.1 - 12.0	88-74 "	400 "
D	12.1 - 18.0	74-60 "	300 "
E	18.1 - 24.0	60-50 "	200 "

*For reduction of wind erosion these strips should not be more than 90 feet in width.

**Length of slope is the distance water normally travels overland before entering a water channel.

Good seeds planted at suitable rates are essential in profitable farming. Adapted certified seeds of recommended varieties should as a rule be used. The rates of planting corn vary with the soil management group and the expected crop yields as shown in the supplemental nitrogen fertilization recommendations in table 7.

Fertilizer recommendations are given in the following pages for the various soil management groups assuming that the yields given there are expected for the crops grown, that soil tests of the plow layer are available, and that the fertilizer is placed as recommended for the particular crop. Where higher yields are expected, the additional amounts of plant nutrients shown in table 6 should be supplied for each of the designated unit increases of yield for the particular crop.

P is low, for barley, hay, oats, pasture, rye or soybeans if the test is less than 35; for alfalfa, corn, field beans, peas, or wheat if the test is less than 50; for potatoes, sugar beets or vegetables if the test is less than 70; and high if the test is greater than these amounts for the crops specified.

K is low if the test shows less than 200, and high if more than that amount when tested by the 1N neutral ammonium acetate method as in the State Lab. Where the soil tests are made in the county labs with .13N hydrochloric acid extraction, 150 is the dividing line between high and low K.

Fertilizer placements are important for the most efficient use of the nutrients by the crop. Recommended placements are as follows:

Corn. Band all or at least a portion of the fertilizer two inches to the side and two inches below the seed. If the planter is the split boot type, reduce the in-row application to 75 to 150 pounds of fertilizer per acre, depending on soil moisture, and broadcast or drill the balance before plowing. If preferred, a large portion of the fertilizer may be plowed down but some nitrogen (10 pounds or more) and most of the phosphate (40 pounds or more) should be applied in the row as a starter.

Table 6. Increased fertilizer rates recommended for unit increase in yields of different crops above those listed for each soil management group.

Crop	Unit	Lbs. plant nutrients N	P_2O_5	K_2O
Alfalfa	1000 pounds	0	12	22
Beans and soybeans	10 bushels	10	18	20
Sugar beets	1 ton	8	12	6
Clover	1000 pounds	0	10	19
Corn	10 bushels	20	12	12
Oats and barley	10 bushels	5	8	9
Potatoes	100 cwt.	33	27	57
Rye	10 bushels	7	16	12
Wheat	10 bushels	10	14	10

Table 7. Recommended pounds of supplemental nitrogen[1] to apply for corn.

Previous crop and manure applied for corn	Number of plants per acre[3] and expected yields 12,000 70 bu.	14,000 80 bu.	16,000 90 bu.	18,000+ 100 bu.
Good legume[2] + 8 tons manure	0	0	0	0
Good legume[2] + no manure	0	0	30	40
No legume + 8 tons manure	45	60	70	80
No legume + no manure	70	80	90	110

[1] Nitrogen rates are influenced by the organic content of the soil. The 'a' groups of soils require about 20 % more and the 'c' groups of soils require about 20 % less than the figures in this table.

[2] Good legume includes sods which contain more than 50 % legumes in the stand. If the stand is less than 50 % legume, consider it as 'no legume.'

[3] On soils of the 1,2,3,4 or 5 management groups, 16,000, 18,000 or more, 16,000, 14,000 or 12,000 plants per acre respectively for grain and 21,000, 22,500 or more, 21,000, 19,500 or 18,000 plants per acre respectively for silage are suggested for management practices outlined herein.

Beans and soybeans. Apply 1 inch to the side and 2 inches below the seed. Do not apply in direct contact with seed. If the planter is the split boot type, reduce the in-row application to 75-125 pounds per acre depending on soil moisture.

Sugar beets. Apply fertilizer 3 inches below or 1 inch to the side and 2 inches below the seed. An alternate plan for applying fertilizer is to plow down a major part of the fertilizer. However, use 150 to 200 pounds per acre of a fertilizer high in phosphorus as a starter fertilizer.

Small grains, (expecially wheat). Conventional drills place the fertilizer in contact with the grain seed. This may cause poor seed germination especially if the soil is dry. To avoid this injury, do not apply more than a total of 120 pounds of nutrients with the seed. (100 lbs. of 5-20-20 contains 45 pounds of nutrients) The balance of the fertilizer applied could be drilled in either prior to planting or plowed down.

Alfalfa,* (alone or with other legume and grass).

New seedings: Band seed if possible. Alow legume seeds to fall on top of the soil directly above the fertilizer band. To seed bromegrass, either mix the seed with oats if oats are the nurse crop or with the fertilizer. Use press wheels on the drill or trail a cultipacker behind at planting time.

Established stands: Broadcast fertilizer after each harvest year. Anytime when the crop growth and soil conditions permit operation of spreading equipment unless the field is to be broken up the following year is satisfactory. The three most favorable periods for topdressing are (1) late winter or early spring, (2) after the first cutting, or (3) late summer or early fall.

Supplemental nitrogen fertilization should be determined by whether or not the previous crop was a legume and the amount of manure being plowed under. If a legume sod crop precedes the small grain or cultivated crop to be grown, it will provide about 70 pounds of nitrogen per acre during the year. Manure plowed down will provide about 4 pounds of nitrogen per ton applied. Supplemental nitrogen should be used if nitrogen deficiency symptoms appear.

For corn, the supplemental nitrogen should be applied as shown in table 7 just before planting or soon after, preferably by June 25. Dry forms and 'no pressure' nitrogen solution may be applied, either on the soil surface or covered, banded or broadcast, near or between the rows. Anhydrous ammonia and 'pressure solutions' must be placed in the soil with special equipment. Care should be taken not to injure the corn roots with the applicators.

For beans, barley, sugar beets, oats, potatoes, and wheat, amounts of supplemental nitrogen recommended are shown in table 8.

Purchase nitrogen on the basis of cost per pound of actual nitrogen and convenience of application. For the amounts of common nitrogen carriers required for a given amount of nitrogen, see table 9.

Table 8. Recommended amounts in pounds of supplemental nitrogen recommended depending on the previous crops and the amount of manure applied for the crop.

Previous crop and manure applied for the crop	Beans[1]	Beets	Potatoes	Winter barley or oats[2]	Wheat[3]
Good legume* + 8 tons manure	0	0	0	0	0
Good legume* + no manure	0	0	0	0	20
No legume + 8 tons manure	0	30	50	25	30
No legume + no manure	25	60	75	30	40

[1]The Sanilac variety will give better response to nitrogen than vine-type varieties.

[2]If lodging is a problem, do not use nitrogen or reduce the amount. The nitrogen may be applied before planting or anytime within 5 weeks after planting. When nitrogen is cut into the soil with an applicator, across the row operation reduces plant tear out.

[3]If lodging is a problem, do not use nitrogen or reduce the amount. On soil management group 1 or 2, nitrogen may be applied in late fall, after soil temperatures are below 50°F or in winter. On more sandy soil groups, or for spring applications on the finer soils, apply nitrogen as early as possible and no later than April 20th. If anhydrous ammonia is used, apply shortly before planting.

Table 9. Pounds of different nitrogen fertilizers to use.

	Pounds of N desired					
Carrier and percent N	20	30	50	70	90	110
Ammonium sulfate, 21%	95	145	240	335	432	528
Ammonium nitrate, 33%	60	90	150	210	270	330
Synthetic urea, 45%	45	70	115	160	200	245
Anhydrous ammonia, 82%	25	40	65	90	115	145
Nitrogen solutions[1]	Pounds of N desired/percent N in carrier X 100 = pounds of carrier to use.					

[1]Nitrogen solutions will vary in N content. Check with your supplier.

PROPERTIES OF SOIL MANAGEMENT GROUPS AND RECOMMENDATIONS FOR THEIR MANAGEMENT

The properties of each soil management group, problems in its utilization, and management suggestions for efficient production and conservation are given in this section as outlined below:

1. The management groups appear in numerical and alphabetical order: e.g., 1a, 1b, 1c are followed by 2a, 2b..... 2c..... 5c..... Ga, Gc, L and M, respectively.

2. Each of these management groups, except the mucks (M) or organic soils, are discussed as outlined below on one page or two facing pages.

-14-	-15-
GROUPS 1a, 1b, 1c:	
Description:	FERTILIZER RECOMMENDATIONS
Management problems:	Drainage recommendations:
Crop adaptations:	Average crop yields expected
MOST EFFECTIVE CROPPING SYSTEMS	Other production and conservation practices
Lime recommendations:	
Fertilizer placement recommendations	

3. If you have not already located your farm and listed the soils found there, turn first to the instructions inside the front cover.

GROUPS 1a, 1b, 1c

Description: These soils were all developed in limy clay or silty clay materials. The 1a group has light colored surfaces and bright colored subsoils. They occur on nearly level to steep areas with low water tables. The 1b group has moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. The 1c group has dark colored surfaces and grey subsoils. They occur on nearly level to depressional areas and are nearly neutral to alkaline in reaction. All three groups have moderate readily available moisture holding capacities and are very slowly permeable.

Management problems: Group 1a -- (1) maintaining good tilth and organic matter content; (2) control of water erosion; (3) acid, unless limed; (4) need fertilization.

Group 1b -- (1) maintaining good tilth and organic matter content; (2) inadequate drainage; (3) need fertilization, and (4) acid unless limed.

Group 1c -- (1) inadequate drainage; (2) maintaining good tilth and organic matter content; (3) need fertilization; (4) the Charity series is limy and boron or manganese may be needed.

Crop adaptations: Where topography and drainage are satisfactory, all common farm crops are fairly well adapted, except potatoes. Trees are seldom planted except on steep slopes or severely eroded areas where white pine, Austrian pine, ponderosa pine and white spruce are suitable. Reed canary grass does well on the undrained areas.

LEAST PROTECTIVE CROPPING SYSTEMS suggested for controlling erosion, maintaining organic matter and good tilth with indicated erosion control practices on slopes 200 feet long, where crop residues are returned to the soil and plowed under immediately before planting. Applies to groups 1a and 1b; for 1c, see group 2c.

Soil management unit	Erosion control practices				
	None	Minimum tillage	Contour tillage	Strip cropping	Terraces
1aA, 1bA,	MMRRW[1] (78)[2]	RWgm (61)	Not used	Not used	Not used
1aB, 1bB	MMMRW (90)	MMRO (86)	MROW (79)	MMMRRO (80)	MMRRW (78)
1aB3	MMWO (92)	MMMRW (90)	MMMROW (88)	MMRO (86)	MMRRW (78)
1aC, 1aC3	MMW (97)	MMW (97)	MMW (97)	MMMRW (90)	MMROW (85)
1aD, 1aD3	M (99)	M (99)	M (99)	MW (94)	Not recomm.
1aE	Permanent vegetation (grass or trees)				

[1]Rotation symbols: M, meadow, legume-grass; gm, green manure or winter cover; O, spring grains; R, row crops; W, winter grains.

[2]A cropping system in table 4 that has a numerical value of relative protectiveness greater than the one given also can be used for a particular soil management unit and erosion control practice.

Lime recommendations will be found in table 3, page 7.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

Other production and conservation practices: Fall plowing is commonly practiced on these soils on nearly level to gently rolling areas. See also bottom of page 18.

FERTILIZER RECOMMENDATIONS (for soil management groups 1a, 1b and 1c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
ON THESE CROPS WITH THESE YIELDS:	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
Alfalfa[2], alfalfa-brome[2], clover, and sweetclover	2.8 T.	0+60+30	0+60+0	0+30+30	0+30+15
Alfalfa, after each harvest year[2]	2.8 T.	0+40+40	0+40+20	0+20+40	0+20+20
Grass without a legume		50+25+25	50+25+0	50+0+25	50+0+0
Barley[3] or oats[3] with legume seeding	40 bu. or	15+60+30	15+60+15	15+30+30	15+30+15
Barley[3] or oats[3,4] without legume seeding	55 bu.	20+40+20	20+40+20	20+20+20	20+20+20
Field beans[3,4]	23 bu.	12+50+25	12+50+25	12+25+25	12+25+12
Soybeans[3,4]		10+40+20	10+40+10	10+20+20	10+20+10
Sugar beets[3,4,5]	12 T.	12+100+50	25+100+25	25+50+50	25+50+25
Wheat[3,4] rye[4]	35 bu.	15+60+30	15+60+15	15+30+30	15+30+15
Corn[4]	70 bu.	12+50+25	12+50+12	12+25+25	12+25+12

[2]Apply fertilizer containing 1/2 percent boron if pH is above 6.5.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be needed.
[5]Apply fertilizer containing 1/4 percent boron if pH is above 6.5.

Drainage recommendations: Occasionally tile will be needed in the 1a group to intercept seepage on slopes. The soils in group 1b commonly require tile drainage for optimum crop yields. Unless artificial drainage has been supplied, it will be needed dor crops on group 1c soils. Tile should be placed 2 to 4 rods apart and 3 to 4 feet deep in these soils where outlets are adequate. Tile should be covered with straw or other porous backfill material. They should be placed above seep spots on slopes at a depth of 3 to 4 feet or on impermeable layer when present but not less than 30 inches deep. Catch basins with sump pumps may be used where natural tile outlets are not available. Plowing in narrow lands (bedding) and leaving the dead furrows for surface drains also help to remove surface water.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grains will be about 30% less on severely eroded areas that can be cultivated.

Crops	Soil management group 1a	1b	1c	Crops	Soil management group 1a	1b	1c
Corn (bu)	74	65	90	Barley (bu)	45.	45.	50.
Field beans (bu)	22	(20)	30	Alfalfa (tons)	3.2	3.4	3.7
Soybeans (bu)	30	28	30	Mixed hay (tons)	2.2	2.4	2.7
Sugar beets (tons)	14	12	16	Pasture (cow days)	90.	105.	115.
Wheat (bu)	38	40	50	Aspen (cords)	1.0	0.65	-
[illegible]s (bu)	68	60	80	White pine (bd.ft.)	165.	-	-

GROUPS 2a, 2b

Description: These soils were all developed in limy loam or clay loam materials. The 2a group has light colored surfaces and bright colored subsoils. They occur on nearly level to steep well drained areas with low water tables. The 2b group has moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Both groups have moderately high readily available moisture holding capacities, and are slowly permeable.

Management problems: Group 2a - (1) control of water erosion; (2) maintaining good structure and organic matter content; (3) acid unless limed, except for the Gagetown series; (4) need fertilization.
Group 2b - (1) maintaining good structure and organic matter content; (2) inadequate drainage; (3) need fertilization; and (4) acid unless limed.

Crop adaptations: All common farm crops are well adapted where topography and drainage are satisfactory. Seldom planted to trees except on severely eroded or steep areas. White pine, Austrian pine, Norway spruce and ponderosa pine are suitable for that purpose. Alfalfa, red clover, and bromegrass are adapted pasture plants.

LEAST PROTECTIVE CROPPING SYSTEMS suggested for controlling erosion, maintaining organic matter and good tilth with indicated erosion control practices on slopes 200 feet long, when crop residues are returned to the soil and plowed under immediately before planting. Applies to groups 2a, 2b, 3b, 3c, 3/1 and 3/2.

Soil management or land capability units	Erosion control practice				
	None	Minimum tillage	Contour tillage	Strip cropping	Terraces
2aA,2bA,3/2aA,3/2bA,3/1bA	ROgm[1] (57)[2]	RgmR (28)	Not used	Not used	Not used
2aB,2bB,3/2aB,3/2bB,3/1bB	MRW (87)	MROgmW (80)	MMRRO (77)	MMMRRO (80)	ROgm (57)
2aB3,3/2aB3	MMMMRO (91)	MMRO (86)	MMMRRO (80)	MMMRRO (80)	MRROW (69)
2aC,2aC3,3/2aC,3/2aC3	MMO (96)	MW (94)	MMO (96)	MMMROW (88)	MRO (78)
2aD,2aD3,3/2aD,3/2aD3	MMW (97)	MMW (97)	MMW (97)	MMOW (93)	Not recommended
2aE,3/2aE	Permanent vegetation - grass or trees				

[1]Rotation symbols: M, meadow, legume-grass; gm, green manure or winter cover; O, spring grains; R, row crops; W, winter grains.
[2]A cropping system in table 4 that has a numerical value of relative protectiveness greater than the one given also can be used for a particular soil management unit and erosion control practice.

Lime recommendations will be found in table 3 on page 7.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

FERTILIZER RECOMMENDATIONS (for soil management groups 2a and 2b) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THESE YIELDS:					
Alfalfa,[2] alfalfa-brome,[2] clover, and sweetclover	3.3 T.	0+80+40	0+80+20	0+40+40	0+40+20
Alfalfa after each harvest year[2]	3.3 T.	0+60+60	0+60+30	0+30+60	0+30+30
Grass without a legume	-	50+25+25	50+25+0	50+0+25	50+0+0
Barley[3] or oats[3] with legume seeding	50 bu. 70 bu.	20+80+40	20+80+20	20+40+40	20+40+20
Barley[3,4] or oats[3,4] without legume seeding	50 bu. 70 bu.	30+60+30	30+60+30	30+30+30	30+30+30
Field beans[3,4]	28 bu.	12+50+25	12+50+12	12+25+25	12+25+12
Soybeans[3,4]	25 bu.	10+40+20	10+40+10	10+20+20	5+20+10
Wheat[3] or rye[3] with legume seeding	40 bu.	22+90+45	22+90+22	22+45+45	22+45+22
Wheat[3,4] or rye[4] without legume seeding	40 bu.	20+80+40	20+80+20	20+40+40	20+40+20
Sugar beets[3,4,5]	14 T.	30+120+60	30+120+30	30+60+60	30+60+30
Corn[4]	80 bu.	15+60+30	15+60+15	15+30+30	15+30+15

[2]Apply fertilizer containing 1/2 percent boron if pH is above 6.5.
[3]Apply fertilizer containing 1 to 2 percent manganese if pH is above 6.9.
[4]Supplemental nitrogen may be needed.
[5]Apply fertilizer containing 1/4 percent boron if pH is above 6.5.

Drainage recommendations: Soils in group 2b commonly require tile drainage for optimum crop yields. Occasionally, tile may be needed on inadequately drained spots in the 2a group or to intercept seepage on slopes. Tile should be placed 4 to 6 rods apart and 3 to 4 feet deep in these soils.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grain crops will be about 20% less on severely eroded areas that can be cultivated.

Crops	Soil management group 2a or 3/2a	Soil management group 2b or 3/2b	Crops	Soil management group 2a or 3/2a	Soil management group 2b or 3/2b
Corn (bu.)	80.	90.	Oats (bu.)	76.	83.
Corn silage (tons)	13.	15.	Barley (bu.)	51.	55.
Field beans (bu.)	25.	28.	Alfalfa (tons)	3.4	3.7
Soybeans (bu.)	30.	30.	Mixed hay (tons)	2.4	2.7
Sugar beets (tons)	14.	16.	Pasture (cow days)	100.	115.
Potatoes (cwts.)	220.	220.	Aspen (cords)	1.3	0.8
Wheat (bu.)	42.	46.	White pine (bd.ft.)	300.	-

Other production and conservation practices: See bottom of page 18, items 1-4 and 8-10.

GROUP 2c

Description: These are dark colored, naturally poorly drained soils, that have been formed in loam to clay loam materials. They occur on nearly level to depressional areas. Their reaction is usually nearly neutral at the surface but the Wisner, Thomas, Tappan, and Whittemore series are limy. These soils are slowly permeable. They have moderate to moderately high readily available moisture holding capacities. These soils are naturally fertile.

Management problems: (1) inadequate drainage; (2) maintenance of organic matter content and good tilth; (3) fertility maintenance and micronutrient deficiencies (boron, manganese and possibly zinc) for some crops, particularly in limy members.

Crop adaptations: All common farm crops are well adapted if these soils have been adequately drained. Where undrained, these areas may be used for pasture. Reed canary grass is well adapted to such areas. Trees are seldom planted and because of the high water table in undrained areas, the yields of woodlands are generally low.

LEAST PROTECTIVE CROPPING SYSTEMS suggested to maintain organic matter and good tilth is a continuous row crop such as corn with a green manure crop seeded at the last cultivation (Rgm, 36). Any more protective cropping system in table 4 should also be satisfactory.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

Other production and conservation practices important in the success of a cropping system are: 1) adequate drainage (see next page), 2) minimum tillage, described on pages 5-6, 3) use of certified seed of adapted varieties, 4) seed treatment with fungicides and insecticides, 5) application of fertilizers according to test as described on the next page, 6) proper placement of fertilizer as described on page 9, 7) use of supplemental nitrogen fertilizers as outlined on pagell, 8) control of weeds by cultivation or sprays, 9) return of crop residues to the soil, and 10) proper timing of all cultural operations.

FERTILIZER RECOMMENDATIONS (for soil management group 2c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
ON THESE CROPS WITH THESE YIELDS:	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
Alfalfa,[2] alfalfa-brome,[2] clover, and sweetclover	40 T.	0+80+40	0+80+20	0+40+40	0+40+20
Alfalfa, after each harvest year[2]	40 T.	0+60+30	0+60+0	0+30+30	0+30+15
Grass without a legume	-	50+25+25	50+25+0	50+0+25	50+0+0
Barley[3] or oats[3] with legume seeding	60 bu. 80 bu.	20+80+40	20+80+20	20+40+40	20+40+20
Barley[3,4] or oats[3,4] without legume seeding	60 bu. 80 bu.	30+60+30	30+60+0	30+30+30	30+30+15
Field beans[3,4]	32 bu.	15+60+30	15+60+15	15+30+30	15+30+15
Soybeans[3,4]	30 bu.	12+50+25	12+50+12	12+25+25	12+25+12
Wheat[3] or rye[3] with legume seeding	45 bu.	25+100+50	25+100+25	25+50+50	25+50+25
Wheat[3,4] or rye[4] without legume seeding	45 bu.	20+80+40	20+80+20	20+40+40	20+40+20
Sugar beets[3,4,5]	18 T.	40+160+80	40+160+40	40+80+80	40+80+40
Corn[4]	90 bu.	20+80+40	20+80+20	20+40+40	20+40+20

[2]Apply fertilizer containing 1/2 percent boron if pH is above 6.5.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be needed.
[5]Apply fertilizer containing 1/4 percent boron if pH is above 6.5.

Drainage recommendations: These soils need artificial drainage if crops are to be grown successfully. Tile drains should be spaced 4 rods apart and 3 to 4 feet deep. Where a natural outlet is not available, catch basins with sump pumps can be used. The effectiveness of the tile system will be improved by backfilling with straw, grass or surface soil.

Average crop yields expected with management recommended above, are as follows:

Crops		Groups 2cA-B and 3/2cA-B
Corn	(bu.)	95.
Corn silage	(tons)	18.
Field beans	(bu.)	30.
Soybeans	(bu.)	34.
Sugar beets	(tons)	19.
Wheat	(bu.)	46.
Oats	(bu.)	83.
Barley	(bu.)	55.
Alfalfa	(tons)	3.7
Mixed hay	(tons)	2.7
Pasture	(cow days)	125.

GROUPS 3a, 3b, 3c, 3/Ra

Description: These soils were developed in stratified or unstratified sandy loam to silt parent materials or in loamy materials 24 to 42 inches thick over sand and/or gravel or bedrock (R). The 3a group has light colored surfaces and bright colored subsoils. A few, such as the McBride series, have weakly developed fragipans at about 15 to 30 inches in depth. They occur on nearly level to steep areas with deep water tables. Usually acid unless previously limed. The 3b group has moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed but Sanilac series is neutral to limy on the surface. The 3c group has dark colored surfaces and the subsoils are predominantly gray in color. Usually slightly acid to neutral in reaction but the Bach series is limy in the surface. All three groups have moderately high to high readily available moisture holding capacities. All three groups are moderately rapid to moderate in permeability. The 3/Ra group has light colored surfaces and bright colored subsoils. They occur on nearly level to gently rolling areas. Bedrock of limestone or sandstone is within 18 to 42 inches of the surface.

Management problems: Groups 3a, 3/Ra -- (1) control of water erosion, rills form rapidly, (2) need fertilization, (3) usually acid; need lime for legume sods, (4) maintaining organic matter content and preventing crusting after rains, (5) some seep spots may be associated with the fragipan areas or shallow bedrock.
Group 3b -- (1) need fertilization, (2) inadequate drainage, (3) acid unless limed, except for Sanilac series, (4) maintaining organic matter content.
Group 3c -- (1) inadequate drainage, (2) need fertilization.

Crop adaptations: All common farm crops are well adapted where topography and drainage are satisfactory. Among the most productive soils for potatoes. Adapted tree species are red pine, white pine, Austrian pine, Ponderosa pine, white spruce, Norway spruce, Scotch pine, and native hardwoods.

LEAST PROTECTIVE CROPPING SYSTEMS suggested for controlling erosion and maintaining organic matter or good tilth, with the indicated erosion control practices on slopes 200 feet long, when crop residues are returned to the soil and plowed under immediately before planting. Applies to groups 3a, 3/$, 4b, 4c, 4/1 and 4/2. For groups 3b and 3c, see 2a.

Soil management or land capability units	Erosion control practice				
	None	Minimum tillage	Contour tillage	Strip cropping	Terraces
3aA, 4bA, 4cA-B, 4/1bA, 4/2aA, 4/2bA, 4/1cA-B, 4/2cA-B	MRWgmRW[1] (72)[2]	ROgm (57)	not used	not used	not used
3aB, 3aB3, 4bB, 4/1bB, 4/2aB, 4/2aB3, 4/2bB	MMRO (86)	MMRRO (77)	MMRRO (77)	MMMRRO (80)	MRWgmRW (72)
3aC, 3aC3, 3bC, 4/2aC, 4/2aC3	MW (94)	MMOW (93)	MMW (97)	MMRW (87)	MROW (79)
3aD, 3aD3, 3bD, 4/2aD, 4/2aD3	MMW (97)	MMW (97)	MMW (97)	MMWO (92)	Not recomm.
3aE, 4/2aE	Permanent vegetation -grass or trees				

1,2 See footnotes of table on p. 14.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

FERTILIZER RECOMMENDATIONS (for soil management groups 3a, 3b and 3c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
ON THESE CROPS WITH THESE YIELDS:	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
Alfalfa,[3] alfalfa-brome,[3] clover, and sweetclover	3.0 T.	0+80+80	0+80+40	0+40+80	0+40+40
Alfalfa, after each harvest year[3]	3.0 T.	0+45+90	0+45+45	0+30+90	0+22+45
Grass, without a legume	-	50+25+25	50+25+0	50+0+25	50+0+0
Barley[2] or oats[2] with legume seeding	45 bu. 65 bu	15+60+60	15+60+30	15+30+60	15+30+30
Barley[2,4] or oats[2,4] without legume seeding	45 bu. 65 bu.	25+50+50	25+50+25	12+25+50	25+25+25
Field beans[2,4]	24 bu.	15+60+60	15+60+30	15+30+60	15+30+30
Soybeans[2,4]	22 bu.	10+40+40	10+40+20	10+20+40	10+20+20
Wheat[3] or rye with legume seeding	35 bu.	20+80+80	20+80+40	20+40+80	20+40+40
Wheat[2,4] or rye[4] without legume seeding	35 bu.	15+60+60	15+60+30	15+30+60	15+30+30
Sugar beets[2,3,4]	12 T.	30+120+120	30+120+60	30+60+120	30+60+60
Corn[4]	75 bu.	15+60+60	16+60+30	15+30+60	16+30+30
Potatoes[2,4]	250 cwt.	40+160+160	40+160+80	40+80+160	40+80+80

[2]Where the soil pH is above 6.9, apply fertilizer containing 1 or 2 percent manganese.
[3]Apply fertilizer containing 1/4 percent boron for sugar beets and 1/2 percent for alfalfa if pH is above 6.5.
[4]Supplemental nitrogen may be needed.

Drainage recommendations: Occasionally tile will be needed just above seep spots on slopes in the 3a group. Tile should be placed 3 to 4 feet deep or just above an impermeable layer if one is present. The soils in groups 3b and 3c commonly require drainage for optimum crop yields. Tile lines should be placed 5 to 7 rods apart and 3 to 4 feet deep. If tile are laid in sandy or coarse silty materials, special blinding should be used to prevent these materials from filling the tile. Because ditch banks in stratified materials are unstable when wet, tile lines should be installed when the soils are not wet.

Average crop yields expected with practices recommended ~~above on uneroded to~~ moderately eroded soils. Yields of non-legume row crops or small grain will be about 10% less on severely eroded areas that can be cultivated. Yields of crops on the 3/Ra group will be 20--30% less than cited below.

Crop		Soil management groups 3a, 4/2a	3b, 4/2b, 4/1b	3c, 4/2c, 4/1c	Crop		Soil management groups 3a, 4/2a	3b, 4/2b, 4/1b	3c, 4/2c 4/1c
Corn grain	(bu.)	75.	80.	85.	Oats	(bu.)	68.	80.	80.
Corn silage	(tons)	12.	13.	14.	Barley	(bu.)	46.	50.	55.
Field beans	(bu.)	22.	25.	26.	Alfalfa	(tons)	3.0	3.3	3.4
Soybeans	(bu.)	25.	26.	27.	Mixed hay	(tons)	2.2	2.6	2.4
Sugar beets	(tons)	11.	14.	15.	Pasture	(cow days)	90.	100.	105.
Potatoes	(cwt.)	250.	240.	240.	Aspen	(cords)	1.3	0.8	-
Wheat	(bu.)	39.	42.	45.	Red pine	(bd. ft.)	325.	250.	-

GROUPS 3/1b, 3/1c, 3/2a, 3/2b, 3/2c

Description: These soils are developed in stratified sandy loam materials 14 to 42 inches thick over clay to silty clay (3/1) or 18 to 42 inches of stratified sandy loam on clay loams, or loam (3/2) materials. The 3/2a soils have light colored surfaces and bright colored subsoils. They have clay to loam substrata. These soils occur on nearly level to steep areas with deep water tables. Usually acid unless previously limed. The 3/1b and 3/2b groups have moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless limed except for the McGregor series which is limy. The 3/1c and 3/2c groups have dark colored surfaces and the subsoils are predominantly grey in color. Usually only slightly acid to neutral in reaction; seldom need lime. All three groups have moderately high readily available water holding capacities. The upper part is rapidly to moderately rapidly permeable and the lower part is slowly (3/2) to very slowly (3/1) permeable.

Management problems: Group 3/2a -- (1) control of erosion, (2) needs fertilization, (3) usually acid and needs lime for legume sods, (4) maintaining organic matter and good tilth.

Group 3/1b and 3/2b -- (1) needs fertilization, (2) inadequate drainage, (3) usually acid, except for McGregor series which has limy surface, (4) maintaining organic matter content.

Group 3/1c and 3/2c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptations: All common farm crops are well adapted where topography and drainage are adequate. Among the most productive soils for potatoes. Seldom planted to trees except on eroded or steep areas. Adapted species for that purpose are white, red, Austrian, Ponderosa and Scotch pine or Norway spruce. Red pine is not adapted to areas where the limy or neutral subsoil is exposed.

LEAST PROTECTIVE CROPPING SYSTEMS recommended on the 3/2a, 3/1b, or 3/2b and 3/1c or 3/2c soils are the same as those recommended for groups 2a.

FERTILIZER RECOMMENDATIONS for the 3/2a, 3/1b or 3/2b and 3/1c or 3/2c soil groups are the same as those recommended on the 3a, 3b and 3c groups, respectively.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

Lime recommendations are given in table 3, page 7.

Drainage recommendations: Occasionally, tile will be needed just above seep spots on slopes in the 3/2a group. Tile should be placed 3 to 4 feet deep or just above the finer substratum, but not less than 30 inches deep. On the 3/1b and 3/1c groups the tile lines should be 2 to 4 rods apart and on the 3/2b and 3/2c groups the tile lines should be 4 to 6 rods apart and 3 to 4 feet deep. Some wet spots can be drained by tile spurs. Surface drainage should be used whenever necessary to prevent ponding of water. Because of the variable depth of the finer substratum, on site investigations should be made before designing the tile system in each field. Some wet spots may lack adequate outlets. These areas may be fertilized and seeded for permanent pasture. Reed canary grass is well adapted to such areas. Alternatively, catch basins and sump pumps may be used to provide adequate outlets.

Average crop yields expected on the 3/2a, 3/1b or 3/2b and the 3/2c or 3/1c groups are similar to those cited for group 2a.

GROUPS 4/1b, 4/1c, 4/2a, 4/2b, 4/2c

Description: All of these soils are developed in sands to loamy sands 14 to 42 inches thick over clay or silty clay (4/1) or sands to loamy sands 18 to 42 inches thick over clay loams or loam (4/2). The 4/2a soils have light colored surfaces and bright colored subsoils. They occur on nearly level to steeply sloping areas with deep water tables and may be underlain by clays, silty clays, clay loams or loam. Usually acid unless previously limed. The 4/1b and 4/2b soils have moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed. The 4/1c and 4/2c soils have dark colored surfaces and the subsoils are predominantly grey in color. They are commonly only slightly acid to neutral but the Essexville series has free lime in the surface. All these soils have moderate to moderately high available water holding capacities. Their upper parts are rapidly to very rapidly permeable and the lower parts are slowly permeable in the 4/2 and very slowly permeable in the 4/1 groups.

Management problems: Group 4/2a -- (1) water and wind erosion control, (2) need fertilization, (3) usually acid and need lime for legume sods, (4) maintaining organic matter content.

Groups 4/1b and 4/2b -- (1) need fertilization, (2) inadequate drainage, (3) usually acid and need lime for legume sods.

Groups 4/1c and 4/2c -- (1) inadequate drainage, (2) need fertilization.

Crop adaptations: Where topography and drainage are adequate, all common farm crops are well adapted, except sugar beets and field beans. Adapted tree species for planting the better drained areas are red, white, Austrian, or Scotch pines. These species and Norway spruce are also adapted to some of the imperfectly drained areas.

LEAST PROTECTIVE CROPPING SYSTEMS recommended on the 4/2a; 4/1b or 4/2b; and 4/1c or 4/2c groups are the same as those for 3a. Windbreaks or strip cropping may be needed on cultivated fields to reduce wind erosion. A field cultivator is useful in preparing sloping hay or pasture areas for grain crops or reseeding so as to leave crop residues on the surface to reduce erosion.

FERTILIZER RECOMMENDATIONS for the 4/2a, 4/1b or 4/2b and 4/1c or 4/2c groups are the same as those for the 4a group.

Lime recommendations are given in table 3, page 7.

Drainage recommendations: Occasionally, tile will be needed just above seep spots on slopes in the 4/2a group. The tile should be placed 3 to 4 feet deep or just above the finer substratum but not less than 30 inches deep. On the 4/1b or 4/1c groups tile lines should be 2 to 4 rods apart and on the 4/2b or 4/2c groups the tile lines should be 4 to 6 rods apart. On all these groups they should be 3 to 4 feet deep. Some wet spots can be drained by tile spurs. Tile should be blinded with topsoil or straw to prevent sand filling them. It may be necessary to lay the tile when the soil is not wet. Surface drainage should be used wherever necessary to prevent ponding.

Average crop yields expected on the 4/2a, 4/1b or 4/2b and 4/1c or 4/2c groups are similar to those cited for the 3a, 3b and 3c groups, respectively.

Other conservation and management practices: See bottom of page 18, items 2-4 and 8-10.

GROUPS 4a, 4b, 4c, 4/Ra, 4/Rb

Description: These soils are developed in stratified or unstratified loamy sand materials, sandy loam materials on stratified sands and gravel within 42 inches, or in sands or loamy sands with thin finer textured bands within 36 inches of the surface. The 4a group has light colored surfaces and bright colored subsoils. It occurs on nearly level to steep areas with low water tables. Usually acid unless previously limed. The 4b group has moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed. The 4c group of soils has dark colored surfaces and the subsoils are predominantly grey in color. Usually slightly acid to neutral in reaction. All three groups have moderately high to high readily available moisture holding capacities. All three groups have moderately rapid to rapid permeabilities. The 4/Ra and 4/Rb soil groups are underlain by limestone or sandstone bedrock within 18 to 42 inches of the surface. They are more droughty than the 4a and 4b groups.

Management problems: Group 4a, 4/Ra -- (1) control of erosion, rills form readily, (2) needs fertilization, (3) usually acid, need lime for legume sods, (4) maintaining organic matter content.
Group 4b, 4/Rb -- (1) needs fertilization, (2) inadequate drainage, (3) acid unless limed, (4) maintaining organic matter content.
Group 4c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptations: Where topography and drainage are satisfactory, all common farm crops are fairly well adapted except sugar beets and field beans. Adapted tree species for planting on the well drained group are red pine, white pine, Scotch pine and jack pine. White pine, Austrian pine or Norway spruce are adapted to some of the imperfectly drained areas.

LEAST PROTECTIVE CROPPING SYSTEMS suggested for controlling erosion and maintaining organic matter and good tilth, with the indicated erosion control practices on slopes 200 feet long, when crop residues are returned. Applies to 4a, 5b, 5c and 5/2b. For groups 4b and 4c, see group 3a.

Soil management or land capability units	Erosion control practice				
	None	Minimum tillage	Contour tillage	Strip cropping	Terraces
4aA,4/RaA,4/Rb,5/2aA, 5bA,5/cA-B,5/2bA	MMRgmRW[1] (80)[2]	MRROW(69)	not used	MMMRRO(80)	not used
4aB,4aB3,4/RaB,4/RbB, 5bB	MMROW (85)	MMRRO(77)	MMRgmRW (90)	MMMRRO(80)	MMRgmRW(80)
4aC,4aC3	MW (94)	MMWO (92)	MMMRW (90)	MMROW (85)	MMRgmRW(80)
4aD,4aD3	MMW (97)	MMW (97)	MMW (97)	MMWO (92)	Not recomm.
4aE,5/2aE	Permanent vegetation - grass or trees				

[1,2]See footnotes of table on p. 14.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

Lime recommendations will be found in table 3, page 7.

FERTILIZER RECOMMENDATIONS (for soil management groups 4a, 4b and 4c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THESE YIELDS:					
Alfalfa,[2] alfalfa-brome,[2] clover and sweetclover	2.7 T.	0+60+60	0+60+30	0+30+60	0+30+30
Alfalfa after each harvest year[2]	2.7 T.	0+45+90	0+45+45	0+30+90	0+22+44
Grass without legume	-	50+25+25	50+25+0	50+0+25	50+0+0
Barley[4] or oats[4] with legume seeding	35 bu. 55 bu.	12+50+50	12+50+25	12+25+50	12+25+25
Barley[3,4] or oats[3,4] without legume seeding	35 bu. 55 bu.	16+32+32	16+32+16	8+16+32	16+16+16
Field beans[3,4] and soybeans[3,4]	18 bu.	10+40+40	10+40+20	10+20+40	10+20+20
Wheat[4] or rye[5] with legume seeding	30 bu.	15+60+60	15+60+30	15+30+60	15+30+30
Wheat[3,4] or rye[3] without legume seeding	30 bu.	12+50+50	12+50+25	12+25+50	12+25+25
Corn[3]	60 bu.	10+40+40	10+40+20	10+20+40	10+20+20
Potatoes[3,4]	200 cwt.	30+120+120	30+120+60	30+60+120	30+60+60

[2] Apply fertilizer containing 1/2 percent boron if pH is above 6.5.
[3] Supplemental nitrogen may be needed.
[4] Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.

Drainage recommendations: The 4b and 4c groups need improved drainage for most crops. They can be adequately drained with open ditches or by tile lines 6 to 8 rods apart. To prevent the tile lines from filling with sand they should be blinded with topsoil, straw or similar materials. It may be necessary to delay ditching and tiling until the dry season of the year.

Average crop yields expected with practices recommended above. Yields of crops on the 4/Ra and 4/Rb groups are 30-40 percent less than cited below and yields on the 5/2a and 5/2b groups are 10-20 percent less than cited below.

Crops	Soil management group 4a or (/a)	4b or (/b)	4c
Corn grain (bu.)	55.	65.	70.
Corn silage (tons)	10.	11.	12.
Field beans (bu.)	15.	18.	20.
Soybeans (bu.)	18.	20.	22.
Sugar beets (tons)	9.	11.	13.
Potatoes (cwts.)	225.	235.	240.
Wheat (bu.)	30.	35.	38.
Oats (bu.)	50.	55.	60.
Barley (bu.)	32.	39.	42.
Alfalfa (tons)	2.7	3.1	3.3
Mixed hay (tons)	1.8	2.1	2.2
Pasture (cow days)	65.	75.	90.
Aspen (cords)	0.8	0.6	-
Red pine (bd. ft.)	300.	250.	-

GROUPS 5a, 5b, 5b-h, 5c, 5.3a, 5a-h, 5.7a —

Description: These soils were formed in sands over 66 inches deep but some of the 5c group may have finer textured materials at between 42 and 66 inches beneath the surface. The 5a, 5a-h, 5.3a and 5.7a groups all have light colored surfaces and bright colored subsoils. The upper part of the subsoil is darkest in the 5a or 5a-h and lightest in the 5.7a group. The 5a-h group has a cemented subsoil layer. They all occur on nearly level to steeply sloping areas with deep water tables. The 5b and 5b-h groups have moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. The 5b-h group has a cemented subsoil. The 5c group has dark colored surfaces and the subsoils are predominantly grey in color. The 'a' groups have low to very low readily available moisture holding capacities and this decreases from the 5a to the 5.3a to the 5.7a and 5a-h groups. The 5b and 5c groups have moderate readily available moisture holding capacities. These soils are all very rapidly permeable. The 'a' and 'b' groups are all acid unless previously limed. The 5c group is usually slightly acid to neutral, except the Tobico series which is limy, and the Kinross series which is acid.

Management problems: Group 5a if cultivated -- (1) wind erosion, (2) need fertilization, (3) maintaining organic matter content, (4) drouthiness, (5) acidity.

Groups 5a-h, 5b-h, 5.3a and 5.7a -- reforestation or pasture improvement.

Group 5b -- (1) need fertilization, (2) inadequate drainage, (3) acidity, (4) maintaining organic matter content.

Group 5c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptations: Yields of common farm crops on group 5a are low unless well managed. Fertilization and irrigation have been used successfully for special crops. These soils are best suited to deep rooted crops, winter grains, and short season crops such as potatoes. These were native hardwood lands but many of these areas have been replanted to red or jack pine, or are used for wildlife pasture. The 5a-h, 5b-h, 5.3a and 5.7a groups are best suited for forestry or wildlife. They were native pine lands. The 5b and 5c areas may be fair pasture lands if fertilized and seeded with ladino clover, alsike clover, Dutch white clover, bromegrass, bluegrass, or other suitable species.

LEAST PROTECTIVE CROPPING SYSTEMS suggested for controlling erosion and maintaining organic matter and good tilth, with the indicated erosion control practices on slopes 200 feet long, when crop residues are returned (except for straw preceding a meadow crop which is removed for use as bedding). Applies to groups 5a and 5/2a. For groups 5b and 5c, see group 4a.

Soil management or land capability units	Erosion control practice: None	Minimum tillage	Contour tillage	Strip cropping	Terraces
5aA, 5/2aA	MMRW[1] (87)[2]	MRW (81)	not used	MMRW (87)	not used
5aB, 5aB3, 5/2aB, 5/2aB3	MMRW (87)	MRW (81)	MMRW (87)	MMRW (87)	MMRW (87)
5aC, 5aC3, 5/2aC, 5/2aC3	MMWO (92)	MMMRW (90)	MMRW (87)	MMRW (87)	MMRW (87)
5aD, 5/2D	MMW (97)	MMW (97)	MMW (97)	MMMMRO (91)	Not recomm.
5a-hA-E, 5aD3, 5aE, 5/2D3-E, 5b-hA-B, 5.3aA-E, 5.7aA-E	Permanent vegetation - grass or trees				

1,2 See footnotes of table on p. 14.

Fertilizer placement recommendations for various crops will be found on pages 9 - 11.

Lime recommendations will be found in table 3, page 7.

FERTILIZER RECOMMENDATIONS (for soil management groups 5a, 5b and 5c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the yellow pages.

IF SOIL TEST SHOWS:		P-low K-low	P-low K-high	P-high K-low	P-high K-high
	APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THESE YIELDS:					
Alfalfa,[2] alfalfa-brome,[2] clover, and sweetclover	2.3 T.	0+45+90	0+45+45	0+30+30	0+22+45
Alfalfa after each harvest year[2]	2.3 T.	0+30+90	0+30+30	0+30+90	0+15+45
Grass without a legume	-	30+30+30	30+30+0	30+0+30	30+0+0
Barley[3,4] or oats[3,4] without a legume seeding	25 bu. 40 bu.	16+32+32	16+32+16	8+16+32	16+16+16
Field beans[3,4] and soybeans[3,4]	12 bu.	10+20+40	10+20+20	4+13+40	5+10+20
Wheat[3,4] or rye[4] without legume seeding	25 bu.	12+50+50	12+50+25	12+25+50	12+25+25
Corn[4]	40 bu.	10+40+40	10+40+20	10+20+40	10+20+20
Potatoes[3,4]	150 cwt.	30+60+120	30+60+60	13+40+120	15+30+60

[2]Apply fertilizer containing 1/2 percent boron if pH is more than 6.5.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be needed.

<u>Drainage recommendations</u>: The 5b and 5c groups may be drained with open ditches. If tile are used the lines should be 6 to 8 rods apart and 3 to 4 feet deep. They should be blinded with topsoil, straw or similar material.

<u>Average crop yields expected</u> with practices recommended above.

Crops		Soil management group				
		5.7a	5.3a	5.0a	5.b	5c
Corn grain	(bu.)	-	-	40.	42.	45.
Corn silage	(tons)	-	-	7.	7.	8.
Potatoes	(cwts.)	-	-	180.	200.	220.
Wheat	(bu.)	-	-	22.	24.	26.
Oats	(bu.)	-	-	33.	35.	40.
Alfalfa	(tons)	-	-	2.0	2.0	2.5
Mixed hay	(tons)	-	-	1.2	1.2	1.5
Pasture	(cow days)	-	35.	45.	50.	70.
Aspen	(cords)	-	0.3	0.8	0.3	-
Red pine	(bd. ft.)	130.	240.	270.	240.	-

<u>Other production and conservation practices</u>: Windbreaks are also recommended for control of wind erosion on these sandy soils. See also bottom of page 18, items 2-4 and 8-10.

GROUPS 5/2a, 5/2b

Description: These soils were formed in 42 to 66 inches of sand over loam to clay materials. The 5/2a group has light colored surfaces and bright colored subsoils. These soils occur on nearly level to steeply sloping areas with deep water tables. The 5/2b group has moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Both groups have moderate readily available water holding capacities. They are commonly acid unless limed. The upper part is very rapidly permeable but the lower part is slowly to very slowly permeable.

Management problems: Group 5/2a -- (1) wind and water erosion control, (2) need fertilization, (3) usually acid and need lime for legume sods, (4) drouthiness.

Group 5/2b -- (1) need fertilization, (2) inadequate drainage, (3) wind erosion control, (4) acidity.

Crop adaptations: Deep rooted crops, winter grains, and short season crops are best adapted. Pastures produce well if fertilized and reseeded. Tree species suitable for planting include red pine, jack pine and white pine.

LEAST PROTECTIVE CROPPING SYSTEMS recommended on the 5/2a and 5/2b groups are the same as those recommended on the 5a and 4a groups, respectively. Windbreaks and strip cropping may be needed on cultivated areas to control wind erosion. A field cultivator is useful in preparing sloping hay or pasture areas for grain crops or reseeding so as to leave crop residues on the surface to reduce erosion.

FERTILIZER RECOMMENDATIONS for the 5/2a and 5/2b groups are the same as those for the 5a and 5b groups.

Lime recommendations are given in table 3, page 7.

Drainage recommendations: The 5/2b group can be adequately drained by open ditches or by tile lines 6 to 8 rods apart. To prevent the tile lines from filling with sand, they should be blinded with topsoil, straw or similar materials. It may be necessary to delay ditching and tiling until the dry season of the year.

Average crop yields expected on the 5/2a and 5/2b groups are similar to those cited for groups 4a and 4b, respectively.

Other production and conservation practices: See bottom of page 18, items 2-4 and 8-10.

GROUPS Ga, Gc

Description and management suggestions: These are very cobbly, stony or gravelly areas that should ordinarily remain in permanent vegetation. The Ga areas are well to moderately well drained but the Gc areas are imperfectly to poorly drained. These soils are too stony, cobbly or gravelly to be artificially drained. Areas in pasture should be seeded to adapted species and fertilized wherever possible according to the recommendation for Group 4 soils. Many of these soils contain limestone fragments and do not need lime. Where tree plantings are planned, suitable species are white cedar, white spruce, and white pine.

GROUPS L2a, L2c, L4a, L4c

Description: These are lowland areas along streams that are subject to overflow seasonally. The L2a and L2c groups are developed on stratified moderately coarse (sandy loams) to moderately fine textured (clay loams) alluvium. The L4a and L4c groups are developed in stratified coarse textured alluvium. The 'a' groups have relatively light colored surfaces and relatively bright colored subsoils. They occur in areas with relatively deep water tables. The 'c' groups have relatively dark colored surfaces and mottled or grey subsoils. They occur in areas with seasonally or permanently high water tables. All four groups occur on nearly level areas but winding low ridges and old stream channels frequently are present. These soils are commonly neutral to alkaline in reaction.

Management problems: (1) overflow may damage crops, delay planting and cause deposition of new sediments, or result in erosion along stream banks in these areas; (2) areas are frequently too small, too inaccessable to too cut up by stream channels to be suitable for cultivation; (3) inadequate drainage; and (4) early frost hazards.

Crop adaptations: Many of these soils are used for permanent pastures or wood-lots. Grasses such as smooth brome grass and moisture tolerant legumes such as white, ladino and alsike clover are recommended on imperfectly drained areas. Reed canary grass may be used on poorly drained areas. These areas are seldom planted to trees; red maple and cottonwood are adapted species. Where the areas are large enough and protected from overflow by dredging of the stream channel or building of levees, cultivated crops may be grown. Summer crops such as corn are best adapted. Lime is seldom needed -- if needed, apply as suggested in table 3 on page 7. Fertilize the L2 and L4 groups as recommended for Groups 2 and 4, respectively.

Drainage: Dredging of streams has improved drainage of some areas. Diversion ditches may be needed for interception of water from adjoining uplands. If areas are large enough and protected from overflow, tile can be used as suggested for Group 3 soils.

Expected crop yields are variable because of overflow damage. Where protected from overflow and adequately drained the yield on the L2 group should be similar to those on Group 2 and the yields on the L4 group should be similar to those on Group 4.

GROUPS Mc, Mc-a, M/1c, M/3c, M/4c, M/mc

Description: Organic soils, mucks or peats, 12 inches or more thick. These are nearly level, very poorly drained areas. Except for the extremely acid group (Mc-a) these soils are well supplied with bases and seldom need lime. They are naturally low in potash and phosphorus and often low in manganese, boron, copper, molybdenum and zinc. When adequately drained and properly fertilized they are productive soils.

Mc -- Deep organic soils, over 42 inches thick. The Lupton series may contain free lime in the surface (see also M/mc below).

Mc-a -- Extremely acid organic soils over 12 inches thick. Low in bases. When lime is applied, dolomitic lime is recommended. Amounts shown in table 3 should be mixed with the soil to a depth of 12 to 15 inches. Some areas composed largely of a mixture of sedge and sphagnum peat are used for commercial peat. Where undrained, these areas are used only by wildlife or may produce some wild blueberries. A few areas have been limed, fertilized and used for vegetable production. Nitrogen, copper and molybdenum are commonly low. Manganese may be low after liming.

M/1c -- Shallow organic soils on clays within 12 to 42 inches. Drainage is more difficult than in other organic soils.

M/3c -- Shallow organic soils on loams within 12 to 42 inches.

M/4c -- Shallow organic soils on sands within 12 to 42 inches. These are less durable and less productive than the deeper organic soils or those on finer textured materials.

M/mc -- Shallow organic soils on marl. Tile drainage is difficult. These soils and the Lupton series in group Mc are commonly too limy for onions, spinach, soybeans, lettuce, or wheat. Application of sulfur to lower the pH is not practical where free lime is abundant.

Management problems: Water control (drainage, water table regulation, and irrigation); proper fertilization (including micronutrients); frostiness; wind erosion control; and fire prevention. Some other management problems peculiar to the individual groups are mentioned above.

Crop adaptations: If adequately drained these soils are suitable for many short season, frost resistant or hardy perennial plants or for pasture. Grasses, celery, carrots, or cabbages are frost resistant and spinach, sugar beets, head lettuce, small grains and onions are moderately resistant. Other crops sometimes grown on these soils in Southern Michigan are shown in the table at the end of this section. Intertilled crops can be grown continuously with proper fertilization. Where cleared but undrained, reed canary grass does well. Brome grass, orchard grass, timothy, alsike clover, and ladino clovers are adapted for the better drained areas. Trees are not planted except as windbreaks on drained areas. Native trees grow slowly.

Water control: Organic soils must be artificially drained before they can be cultivated. In most places a system of open ditches 150 to 300 feet apart and tile lines are used. Ideally, the water table should be maintained about 30" below the land surface. This prevents drouthiness and decreases decomposition rate or subsidence of the organic soils and decreases the wind erosion hazard. In some places it has been possible to use a pumping system to lower the water table and make drainage feasible. Irrigation is commonly practiced on organic soils to increase yields of truck crops and decrease frost damage and wind erosion. Where tile drains are installed, long tile (24 inches) help avoid poor alighment due to uneven settling. Back-filling with rawer peat, straw or marsh hay helps to prevent filling of the tile by fine material or sand (in Group M/4c). Clay tile are preferable below a pH of 6.0. Tile should be installed 3 to 5 feet deep and spaced in accordance with the soil properties as indicated below:

Soil management group	Tile	
	Spacing	Depth
Mc	6 rods	4-5 feet
Mc-a	6 rods	4-5 feet
M/1c	3 rods	3-4 feet
M/3c	4-5 rods	3-4 feet
M/4c	Ditches may be adequate	
M/mc	4 rods	3-4 feet

Erosion control: Organic soils are subject to wind erosion when cultivated. This may result in damage to seedlings, filling of drainage ditches and shortening the life of shallow organic soils. The hazard is greatest when the soil is loose and dry. Compacting the surface, maintaining a relatively high water table and irrigation avoid or alleviate these conditions. Strip cropping, buffer strips and windbreaks aid in preventing excessive erosion. White pine, Austrian pine, or green willow are suitable species. Spirea and multiflora rose can also be used but they lack height. Interplanted rows of grains such as wheat, barley or rye 2 or 3 feet apart can be used until the next crop is big enough to protect the surface. In some cases, deep tillage to bring up more fibrous materials or roughen the surface have helped prevent erosion losses.

Frostiness: Maintaining a compact surface, a high water table, and use of sprinkler irrigation systems aid in preventing frost damage to crops and decrease wind erosion.

Other conservation practices: Avoid fires on organic soils. Water table control decreases rate of subsidence.

FERTILIZER RECOMMENDATIONS FOR ORGANIC SOILS: Where not previously fertilized, only pH tests are recommended. If previously fertilized, samples should be taken and tested before fertilizer is to be applied.

Phosphate fertilizer recommendations for organic soils based upon crop and available soil phosphorus using Bray P_1 method

Available soil phosphorus Pounds per acre of "P"				Pounds P_2O_5 per acre recommended
			15	200
		10	30	160
		20	40	130
	10	40	60	100
5	20	60	80	75
15	40	80	110	50
30	60	100+	140+	30
50+	75+	---	---	20
blueberries buckwheat clover grass oats rye soybeans pasture	alfalfa asparagus barley beans corn mint peas radishes sudan grass sweet corn turnips wheat	cabbage carrots cucumbers endive lettuce parsnips potatoes pumpkins spinach sugar beets table beets	broccoli cauliflower celery onions tomatoes	

Recommended amounts of molybdenum and zinc on organic soils when the pH of the surface layer is known.

Element	pH of surface layer		
	<5.5	5.5-6.5*	>6.5
Molybdenum	0.3 lb/acre in band near seed or seed treatment, 1 oz. per bu. of seed	0	0
Zinc	0	0	2-3 lbs/acre for 2-3 years.

*Soils high in iron also show a need for molybdenum. Use rate suggested for a pH <5.5.

Potash fertilizer recommendations for organic soils based upon crop and soil test using the 1N ammonium acetate method

Available soil potassium Pounds of "K" per acre					Pounds K_2O per acre recommended
				100	600
				200	500
			100	300	400
		100	200	400	300
		150	250	450	250
	75	200	300	500	200
	125	250	350	560	160
50	200	300	400	620	130
100	250	350	450	700	100
150	280	380	480	750	80
200	310	410	510	800	60
250	350	450	550	825	40
275	375	475	575	850	20
300	400	500	600	900	0
barley blueberries grass oats rye pasture wheat	beans clover corn mint peas soybeans sudan grass sweet corn turnips	alfalfa asparagus cabbage carrots cucumbers lettuce parsnips radishes spinach	broccoli cauliflower onions potatoes sugar beets table beets tomatoes	celery	

Recommended amounts of manganese, boron and copper on organic soils, when the expected crop response is low, medium, or high and the pH of the surface layer is known.

Expected responses of a crop is shown on the next page.

Element	Expected response	pH of surface layer <5.0-	5.0-5.5	5.5-6.0	6.0-6.5	6.5-7.2	7.3-8.0
Manganese	high	0	0	10	10	20	40*
	medium	0	0	5	5	10	20
	low	0	0	0	0	5	10
Boron	high	3	3	3	5	5	5
	medium	1	1	1	3	3	3
	low	0	0	0	1	1	1
Copper**	high	6	6	4	4	2	2
	medium	4	4	2	2	0	0
	low	2	2	0	0	0	0

*More practical to disc in 500 lbs. per acre of sulfur and use 20 lbs. per acre of manganese, unless free lime is present.

**No more than 20 lbs/acre and 40 lbs/acre of copper are needed for crops with low to medium responses and high responses, respectively.

Micronutrients: Relative responses of various crops to micronutrients on organic soils.

Relative responses of crops to micronutrients on organic soils.

Crop	Micronutrient element response			
	Manganese	Boron	Copper	Others
Alfalfa..............	Low	High	High	
Asparagus............	Low	Medium	Low	
Barley...............	Medium	None	Medium	
Beans................	High	None	Low	Zinc
Blueberries..........	None	None	Medium	
Broccoli.............	Medium	Medium	Medium	Molybdenum
Cabbage..............	Medium	Medium	Medium	Molybdenum
Carrots..............	Medium	Medium	High	
Cauliflower..........	Medium	High	Medium	Molybdenum
Celery*..............	Medium	High	Medium	Sodium
Clover...............	Medium	Medium	Medium	
Cucumbers............	Low	Low	Medium	
Corn.................	Medium	Low	Medium	Zinc
Grass................	Medium	None	Medium	
Lettuce..............	High	Medium	High	Molybdenum
Oats.................	High	None	High	
Onions...............	High	None	High	Zinc, molybdenum
Parsnips.............	Low	Medium	Medium	
Peas.................	High	None	Low	
Peppermint...........	None	None	Low	
Potatoes.............	High	Low	Low	
Radish...............	High	Medium	Medium	
Rye..................	None	None	None	
Spearmint............	Medium	None	Low	
Soybeans.............	High	None	Low	
Spinach..............	High	Medium	High	Molybdenum
Sudan grass..........	High	None	High	
Sugar beets..........	Medium	High	Medium	Sodium
Sweet corn...........	Medium	Low	Medium	
Table beets..........	Medium	High	High	Sodium
Turnips..............	Medium	High	Medium	
Wheat................	High	None	High	

*Certain varieties need 5 to 10 pounds per acre of magnesium sulfate (epsom salts) applied to the foliage weekly.

GROUPS Ra, Rc

Description: R (rocky) -- Very shallow loamy to sandy soils, underlain by bedrock at less than 18 inches from the surface. The bedrock may be sandstone or limestone.

Ra -- Well drained or moderately well drained.
Rc -- Imperfectly or poorly drained.

Management problems and suggestions: Because of the rockiness of these soils and their very shallow nature, they are not suitable for cultivated crops. Where cleared, they are commonly used for permanent pasture. Because of their shallowness, they have low water holding capacities and yields of pastures and timber are low. Where the bedrock is suitable, these areas may be valuable as quarries for limestone, gypsum, building stones, or abrasives. They have some value as wildlife and recreational areas.

GROUPS Sa, Sc

Sa -- Miscellaneous, well drained, non-agricultural land types. Includes borow, clay, sand or gravel pits; lake beaches - sandy, gravelly, stony or rocky; dunes; madeland and steep gullied land. These areas are suitable for wildlife and recreational purposes. The beaches may be valuable water frontage for summer homesites, parks or resorts.

Sc -- Miscellaneous, imperfectly to poorly drained, non-agricultural land types. Includes lake marsh and wet swales. These areas are best utilized for water fowl, muskrats or other aquatic wildlife.

HOW SOIL MAPS ARE MADE

Satisfactory soil maps can be made only by actually observing the soils in the field. Today the boundaries between the different kinds of soils are plotted on aerial photographs of the area by soil scientists as they walk across the fields systematically observing the soil characteristics not only at the surface but also to depths of 42 to 66 inches with the aid of soil augers. It is possible to make an accurate soil map of an area with a minimum of auger borings only when the relationships among the different soils present and the factors associated with their differences are known. Some of these relationships are discussed in the front of this circular and in somewhat more detail in Special Bulletin 402 -- Soils of Michigan -- of the Michigan Agricultural Experiment Station. Aerial photographs are a great aid in accurately drawing the boundaries between the different kinds of soils in an area. Many reference points (such as houses, fields, roads, and streams) are visible on the aerial photographs and many soil differences also show up because of the differences in the color of the soils or the crops growing on them at the time the photographs were taken. In Michigan, as in most other parts of the United States, the soils are being mapped cooperatively by the Soil Conservation Service of the U.S.D.A. and the State Agricultural Experiment Station. In addition, the U. S. Forest Service cooperates in the mapping of lands in National Forests. This cooperative endeavor is known as the National Cooperative Soil Survey.

HOW SOILS ARE NAMED

Taxonomic units:

Each soil or taxonomic unit differs in the properties of one or more of its horizons or of the whole soil body such as its shape, from every other unit. The soil series* name, the capitalized part of the soil's name, such as Marlette, stands for all the characteristics of the soil body used in the soil's classification except those that are easily observable at or near the surface of the land, such as the texture of the plow layer or the slope of the soil surface.

Differences within each soil series that are observable at or near the land surface are indicated by the short descriptive terms or phrases accompanying the series name. For example, Marlette loam, 6-12% slope, slightly eroded, is a Marlette soil with a loam surface, that occurs on slopes of from six to twelve percent, and has had a small part of its natural upper layers removed by erosion. The series name plus the texture of the surface soil is the soil type name.

Mapping units:

Each mapping unit, that is all areas on a soil map containing identical symbols, is composed predominantly of the soil or taxonomic unit (or units) mentioned in its name. In addition, other soils not practical or possible to separate (at the scale of the map used or in the time available for doing the work), are also present. Descriptions of each of the soils and mapping units in an area can be found in the published soil survey reports, where one is available.

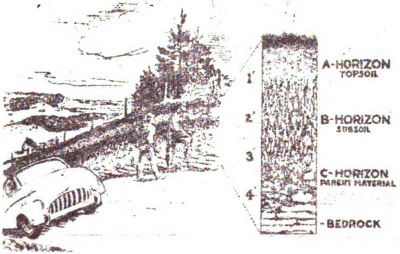
*The soil series name is taken from some geographic feature (e.g. the name of a town, stream, township, etc.) near where it was first described. The Marlette series was named after the town in Sanilac County.

APPENDIX G

1964 "KNOW YOUR SOILS"

KNOW YOUR SOILS
AND HOW TO USE THEM

"...RETAINING THE MAXIMUM FERTILITY OF THEIR SOIL. THERE IS NO SUBJECT TO OUR PEOPLE OF PROFOUNDER CONCERN, OR OF MORE FAR REACHING IMPORTANCE." J. S. MORRILL



Prepared by

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U.S. DEPT. OF AGRICULTURE
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COOPERATIVE EXTENSION SERVICE, MICHIGAN

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HOW THIS INFORMATION CAN BE USED:

If you are interested in the general nature of the soils of your county and how their properties are important to their use for various purposes, you will find these matters discussed in the general colored sections of this report.

If you are interested in the soils on a particular area in your county, refer to the soil management group that applies, in the white section, as follows:

1. Locate the area on the index map. A copy is available through the Cooperative Extension Service or the Soil Conservation Service. The towns, township names, (or township and range numbers), section numbers, roads, railroads and streams should assist in this process. On the index map you will find the reference number for the soil map of your area.
2. Outline the boundaries of your farm on the soil map. A recent county plat book will help you locate the tract. School houses and farm homes are also shown on the soil map. Be sure to note any differences in the scales of the index and soil maps and which direction is north!
3. List the mapping units shown on your farm into a table with column headings as in table 1 below.
4. Copy the names of the soil types and the soil management group designation of each into column 2 and 3 of table 1 from the list of soil mapping units. The slope class and erosion class follow the soil type portion of the mapping unit symbol.
5. Brief descriptions of these soil management groups and suggestions on their management, and their productivity for various crops when well managed, are given for each management group in numerical and/or alphabetical order following the general sections. For example, the 2a, 2b groups will be found immediately after the 1a, 1b, 1c groups and the 2c group will follow the 2a, 2b groups, if all are present on your farm. The group designations beginning with a letter follow those beginning with numbers. Thus, the L and M groups follow the groups designated 5/2a, 5/2b, Ga and Gc. Compare these descriptions and the accompanying information with what you know about the soils on your farm and how you are managing each! Copy the names of the soils on your farm in each group, and their soil management unit designations onto the front page of the section for each group.
6. Outline changes in the use or management of your soils that would be likely to increase the net economic returns from your land or otherwise increase your satisfaction from its wise utilization. Plan to incorporate these changes in your management plans for each field. Repeating steps 3, 4, and 5 for individual fields may help you do this.
7. If further information is needed, consult the county Cooperative Extension Service or Soil Conservation Service representative.

Table 1. Soils on my farm.

Mapping unit symbol	Soil names	Soil management unit		
		Soil management group	Slope class	Erosion class
450C2	Miami loam, 6-12% slopes, mod.eroded	2a	C	2

SOIL MAPS, SOIL PROPERTIES, SOIL MANAGEMENT GROUPS, AND SOIL SAMPLING

Are you taking full advantage of all the useful information available about the kinds of soils in your county? In addition to its usefulness in soil management, such information can be helpful in:

1) land evaluation for various purposes, such as security for loans, purchase or sale values, or assessments of various kinds;
2) determining suitability for urban, industrial, agricultural or constructional uses;
3) the design of roads, drainage systems, irrigation systems, sewage disposal systems or foundations for buildings;
4) location of sites suitable for expanding business ventures such as production of foods or fibres, or establishment of plants suitable for their processing and marketing.

Information on availability of soil maps for your county are available at either the county office of the Cooperative Extension Service or the Soil Conservation Service.

This publication summarizes some of the useful information about soils in your county. Knowledge of what these soils are and where each kind is found is the result of cooperative studies by the U. S. Department of Agriculture, the Michigan Agricultural Experiment Station and other cooperating agencies over the past 60 years. How this information is gathered and how the soil maps are made is discussed on the back cover of this circular. The ideas concerning the utilization, management, and productivity of these soils are based upon research and the experiences of users of similar soils.

The first part of this circular discusses how the soils differ from each other, how they can be grouped for management purposes and how their differences are important in their utilization. The following pages give information on: the properties of each soil management group, its management problems, the crops adapted to each, suitable crop rotations, conservation practices for controlling erosion and maintaining yields, drainage requirements, and fertilizer recommendations.

The expected average crop yields when the recommended management practices are followed for each soil managment group and its subdivision into slope or eroded phases are also listed. These phases of the soil management groups are called soil management units or land capability units. Directions for the use of this more detailed information about soil management groups are given inside the front cover of this circular.

How and why do the soils in this area differ from one another? In plowing a field, one notes in the overturned furrow slice various shades of color ranging all of the way from deep black to light grey or yellow. To the soil scientist these shadings of yellow, grey and black and the sandy to clayey texture mean types of soil that have distinct origins and certain basic characteristics. Each kind of soil needs certain types of treatment to get the most return from that soil. If you were to take a huge axe or hoe and slice down through the soil on one of the fields and lift out a section, like one would a piece of layer cake, the vertical side of this piece of soil cake would also show layers that differ in color and texture. This is called the soil profile. Some soils common to East Central Michigan are shown in Figure 1.

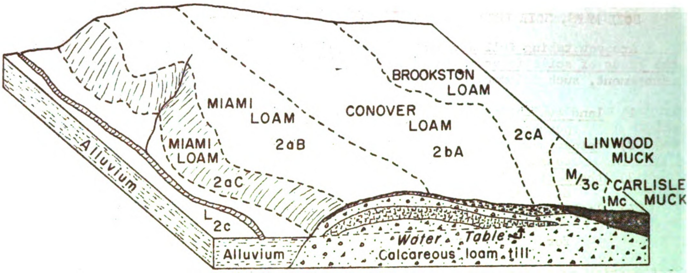


Fig. 1. Landscape showing topographic relationships among the soils and the soil management unit to which each soil belongs.

The difference in these soils are mainly associated with difference in: (1) their age, (2) texture of the parent materials from which they are formed and (3) in natural drainage within the area.

Alluvial soils on the lowland (L) or overflow lands, are still receiving sediments from flood waters. The properties, however, are largely those of the original sediments. Some differences in past drainage are evident in their color and organic content.

Organic or muck soils (M), are found in the most poorly drained upland areas. In these areas, organic matter has accumulated over the original mineral deposits. Where this organic layer is one foot or more thick they are called Organic soils.

What are the soils in your county? The soils in this county are listed with the mapping unit symbols among the information available from the Cooperative Extension Service or the Soil Conservation Service for your area. The soil series names are arranged in the key accompanying the list of mapping units: vertically, according to the texture or the parent materials from those that were formed, from the finest textures at the top of the table (clays) to the coarsest textures at the bottom (sands), and horizontally, on each line are the soils formed from similar kinds of parent materials. Those developed under the best natural drainage conditions (well-drained) are shown at the left and those formed under the poorest natural drainage (poorly or very poorly drained) at the right of the key. In some cases these soils have formed in layers of more than one kind of material. Thus, thin organic soils may form in the most poorly drained sites over mineral materials within 12 to 42 inches of the surface. The young Alluvial soils found on lowlands (L) along streams are shown near the bottom of the key. All of these soils differ from each other in one or more ways that may be important for one or more uses. These differences are described in detailed county soil survey reports.

How may soils be grouped for management purposes? With our present knowledge the soils that have profiles of similar texture or similar materials, similar natural drainage conditions, and similar age, may be grouped together for many management purposes. This grouping places together soil series with similar profile characteristics, similar management requirements and similar productivities when managed similarly. In table 2, these soil management groups are arranged in the same pattern as the soil series in the key dissussed above.

Table 2. Relationships of soil management groups with connotative symbols.

Average texture of soil material or profile in mineral soils and character of organic material	MINERAL SOILS			ORGANIC SOILS	
	Drainage (natural)			Very poorly drained	
	Good	Imperfect	Poor to very poorly	Shallow, 12-42" thick	Deep, 42" thick
	a	b	c	c	c
UPLANDS:					
Clays (over 55%),0	0a	0b	0c		
Clay or silty clay, 1	1a	1b	1c	M/1c	
Clay loams or loam, 2	2a{1.5a 2.5a	2b{2.5b 2.5b	2c{1.5c 2.5c		
Loam to sandy loam, over bedrock at 18-42", 2/R	2/Ra	2/Rc	2/Rc		Mc
Sandy loam, 3	3a	3b	3c		
Sandy loam over clay to silty clay at 14-42", 3/1	3/2a	3/1b	3/1c	M /3c	
Sandy loam over clay loams to loam at 18-42", 3/2	3/2a	3/2b	3/2c		
Loamy sand to sand over clay to silty clay at 18-42",4/1	4/2a	4/1b	4/1c	or	
Loamy sand to sand over clay loam to loam at 18-42", 4/2	4/2a	4/2b	4/2c		
Sand to loamy sand, 4	4a	4b	4c		
Loamy sands to sands over bedrock at 18-42", 4/R	4/Ra	4/Rb	4/Rc	M/4c	
Sands, drouthy, 5	5a	5b	5c	or	Mc-a[2]
very drouthy, 5.3	5.3a,5a-h[1]	5b-h[1]		Mc-a[2]	
extremely drouthy, 5.7	5.7a				
Sands over loam to clay at 42-66", 5/2	5/2a	5/2b	5c		
Stony, cobbly or gravelly, G	Ga	Gc	Gc		
Bedrock at <18", R	Ra	Rc	Rc		
ALLUVIAL SOILS, LOWLANDS, L:					
Moderately fine to moderately coarse textured	L2a	L2c	L2c		
Coarse textured	L4a	L4c	L4c		
MUCKS OR PEATS, over marl, M/m:			M/mc	M/mc	Mc
0-12 inches of muck over marl					
Lake beach, bluffs or dunes	Sa				
Lake marsh and wet swales			Sc		

1. Subsoil cemented with humus and iron oxides.
2. Formed in extremely acid woody and fibrous or fibrous organic materials.

The naturally well drained and moderately well drainted mineral soils have been grouped together in column 'a' toward the left side of table 2 and the poorly to very poorly drained mineral and organic soils are shown at the right side of that table under the columns headed 'c'. The imperfectly drained mineral soils are in between under the column heading 'b'. The very poorly drained organic soils are designated with a capital "M", for mucks or peats. The relationships of some of these soils to one another in a landscape are shown in Figure 1.

Vertically within each of the columns mentioned in table 2, the soils formed in parent materials of similar textures or having similar textures of profiles are grouped together as indicated in the left-hand column. The finest-textured materials are shown at the top, 'fine clays,' accompanied by the number 0. The successively coarser materials are listed lower in the table with the sands as number '5' at the bottom. The Alluvial soils on lowlands, L, are near the bottom of the table.

In table 2 each combination of numbers and letters designates a particular soil management group. These designations tell us a good deal about the properties of the soils in each of those groups and their relationships to one another. For example, in the upper left-hand corner, 0a, the soils have fine textured, clay profiles and are found in naturally well drained conditions on convex slopes with deep water tables. Their surfaces are lighter in color and their subsoils are brighter in color than the poorly drained soils. The poorly drained mineral soils on this line near the upper right-hand corner, 0c, also have fine textured profiles but they have darker colored surfaces and grayer subsoils because they were developed under naturally poorly or very poorly drained conditions. The shallow organic soils over the clay materials are shown as M/1c which tells us they are composed of muck or peat (M) 12 to 42 inches thick over clay (1) materials and were developed under naturally very poorly drained conditions (c). Where the organic materials are more than 42 inches thick, the soils are shown as Mc soils -- that is, deep organic soils (M) which were formed in conditions of very poor natural drainage (c).

<u>How are the properties of these soils important in their use?</u> The soils in the 'c' groups and most of those in the 'b' groups needed artificial drainage before they could be used successfully for most crops. The soils in the 'a' groups do not need artificial drainage but they are subject to water erosion, particularly on the steeper slopes. The 5a groups of soils near the lower left part of table 2 are well drained or moderately well drained (a) soils formed from sands (5). These drouthy coarse-textured soils may be subject to water erosion on slopes but in cultivated areas they are subject to wind erosion even on level areas. Much of the precipitation will be lost by runoff from the well-drained clayey 1a soils, but it will enter streams from the well-drained sandy areas by movement through the soil.

Variations in slopes or degrees of erosion within the better drained soil groups are indicated by adding a capital letter (such as A=0-2%, B=2-6%, C=6-12%, D=12-18%, E=18-25%, F=25%+) to indicate the slope class and a final number for the eroded class, 2=moderately eroded or 3=severely eroded. These map symbols are explained in the legend for the more detailed soils maps that are and may be available for your county. Since water runs off more rapidly on the steep slopes, these soils are more subject to erosion losses and more protective cropping rotations or conservation practices are needed to prevent excessive erosion. These subdivisions of the soil management groups are called soil management units or land capability units.

Within the soil management groups are also Alluvial soils on lowland areas along streams that are subject to seasonal flooding. As a result, these are not suitable sites for home construction and crop production is uncertain. These groups of soils are indicated by a capital letter "L" preceding the profile texture and drainage designations. For example, soils in the L2c group are poorly to imperfectly drained (c), moderately coarse to moderately fine textured (2), lowlands (L) subject to flooding.

Thus, the designations for these soil management groups and their subdivisions enable us to recall much useful information about these soils. They also indicate their relationships to each other in the properties of their profiles and their situation in the landscape.

Further discussion of the important differences among the soil management groups as to their available water-holding capacities, infiltration rates, permeabilities, and runoff, erosion, or leaching losses will be found in Special Bulletin 402, Soils of Michigan, of the Michigan Agricultural Experiment Station.

How to collect soil samples for soil testing.

1. Important: take care in sampling. A soil test can be no better than the sample tested. The samples should accurately represent the fields or parts of fields concerned. Wherever feasible, take a composite sample from each soil type in a field. The soil types can be located with a soil map, or if maps are unavailable, locate the different soils by observing the differences in surface texture and color. Areas of a field that have been treated differently with lime, by heavy manuring, or special cropping systems should also be sampled separately on each soil type. Each composite sample should represent no more than ten acres and should consist of about 20 separate samples representing the plow layer from different points throughout each soil area sampled. Thoroughly mix this composite soil sample and take the sample for testing from this mixtures. Your County Extension Office has detailed instructions on sampling, sampling bags and information sheets to accompany the samples available. Many counties even have a soil sampling service available.

2. To have these soil samples tested, send each of them with the soil type name(where that is available) and the depth of plowing to your Agricultural Extension Agent.

   a) Soil type name, e.g. Miami loam, or Conover sandy loam (this information is available in the published soil survey report of many Michigan counties, on the soil maps of individual farms in the Soil Conservation Districts, or on the field sheets where soil surveys by the National Cooperative Soil Survey are in progress.

   b) Plowing depth is the average depth to which you usually plow the field being tested. If you do not furnish this information to the Extension Agent, his recommendation for liming will be based on a 6-2/3 inch plow layer. You will then need to correct those recommendations as suggested in the section on Liming Michigan Soils for each field.

3. You will want to retest each field every two to five years or at least once in each rotation. There is an advantage to testing during the last sod year of the rotation. Should lime be needed, it can then be added before breaking the sod.

SOIL TESTS AND FERTILIZATION

Fertilizer recommendations are given in the following white pages for the various soil management groups assuming that: the yields given there are expected for the crops grown, that soil tests for the plow layer are available, and that the fertilizer is placed as recommended for the particular crop as suggested below. Where higher yields are expected, the additional amounts of plant nutrients shown in table 6 should be supplied for each of the designated unit increases of yield for the particular crop.

Table 6. Increased fertilizer rates recommended for unit increase in yields of different crops above those listed for each soil management group.

Crop	Unit	Lbs. plant nutrients		
		N	P_2O_5	K_2O
Alfalfa	1000 pounds	0	12	22
Beans and soybeans	10 bushels	10	18	20
Sugar beets	1 ton	8	6	10
Clover	1000 pounds	0	10	19
Corn	10 bushels	20	12	12
Oats and barley	10 bushels	5	8	9
Potatoes	100 cwt.	30	30	60
Rye	10 bushels	7	16	12
Wheat	10 bushels	10	14	10

Soil test interpretations vary with the crop to be grown or the method of testing as follows:

P is low for barley, hay, oats, pasture, rye, soybeans, alfalfa, corn, field beans, peas, or wheat if the test is less than 35; for potatoes, sugar beets or vegetables if the test is less than 70; and high if the test is greater than these amounts for the crops specified.

K is low if the test shows less than 180 and high if more than that amount when tested by the 1N neutral ammonium acetate method as in the State Lab. Where the soil tests are made in the county labs with .13N hydrochloric acid extraction, 150 is the dividing line between high and low K.

Fertilizer placements and timing are important for the most efficient use of the nutrients by the crop. Recommendations for different crops are as follows:

Alfalfa.* (alone or with other legume and grass)

New seedings: Band seed if possible. Allow legume seeds to fall on top of the soil directly above the fertilizer band. To seed bromegrass, either

*If boron is needed, it can be mixed with the fertilizer by the manufacturer.

mix the seed with oats if oats are the nurse crop or with the fertilizer.

Established stands: Broadcast fertilizer after each harvest year. Anytime when the crop growth and soil conditions permit operation if spreading equipment, unless the field is to be broken up the following year, is satisfactory. The three most favorable periods for topdressing are: 1) late winter or early spring, 2) after the first cutting, or 3) late summer or early fall.

Small grains. (especially wheat) The proper place to apply fertilizer for small grains is 1 inch to the side and 1 inch below the seed. Most grain drills place the fertilizer in contact with the grain seed. This may cause poor seed germination especially if the soil is dry. To avoid this injury, do not apply more than a total of 100 pounds of nutrients per acre with the seed for sandy soils and 140 pounds of nutrients per acre with the seed for fine textured soils. (100 lbs. of 5-20-20 contains 45 pounds of nutrients.) The balance of the fertilizer needed can be drilled in either prior to planting or plowed down. Where small grains are likely to lodge use little or no nitrogen.

Potatoes. Apply up to 800 pounds per acre in bands 2 inches to the side and on the level or slightly below the seed piece. Plow down additional amounts if needed. Many growers find it profitable to sidedress with 50 pounds of nitrogen per acre during the growing season. Irrigated potatoes usually need 50 percent more fertilizer because of higher expected yields.

Corn. Band all or at least a portion of the fertilizer two inches to the side and two inches below the seed. If the planter is the split boot type, reduce the inrow application to 75 to 150 pounds of fertilizer per acre, depending on soil moisture, and broadcast or drill the balance before plowing. If preferred, a large portion of the fertilizer may be plowed down but some nitrogen (10 pounds or more) and most of the phosphate (40 pounds or more) should be applied in the row as a starter. Plow down or sidedress nitrogen fertilizer as shown in Table 7.

Beans and soybeans. Apply 1 inch to the side and 2 inches below the seed. Do not apply in direct contact with seed. These crops often need manganese fertilizer. Field beans may also need zinc.

Sugar beets. Apply fertilizer 3 inches below or 1 inch to the side and 2 inches below the seed. Apply supplemental nitrogen early if it appears necessary. An alternate plan for applying fertilizer is to plow down a major part of the fertilizer. However, use 150 to 200 pounds per acre of a fertilizer high in phosphorus as a starter fertilizer.

Vegetables and fruits. For recommendations on fertilization of these crops, see Extension Bulletin E-159 of Michigan State University.

Supplemental nitrogen fertilization should be determined by whether or not the previous crop was a legume and the amount of manure being plowed under. If a legume sod crop precedes the small grain or cultivated crop to be grown, it will provide about 70 pounds of nitrogen per acre during the year. Manure plowed down will provide about 4 pounds of nitrogen, 2.5 pounds of phosphate (P_2O_5), and 8 pounds of potash (K_2O) per ton applied. Supplemental nitrogen should be used if nitrogen deficiency symptoms appear. Deficiencies may be spotted sooner with chemical tests than by visual plant deficiency symptoms. Special Bulletin 353 of the Michigan Agricultural Experiment Station gives further details of nitrogen deficiencies.

Time of nitrogen application is important for sandy soils (management groups 3, 4 and 5) especially if they are irrigated. For these sandy soils, delay application until the time the crop has its greatest nitrogen needs. Time of application of nitrogen on fine textured soils (management groups 1 and 2) may be either late fall, spring, or early summer. Do not apply nitrogen on the surface in the fall or winter for spring-sown crops on land that is subject to water runoff.

For corn, sugar beets, small grains, late potatoes, and beans or soybeans, amounts of supplemental nitrogen recommended are shown in Table 7.

Table 7. Guide for estimating the total pounds of nitrogen (N) fertilizer per acre needed by field crops as affected by previous management. Subtract from the total the nitrogen applied at planting time* to determine the amount of supplemental N needed.

Plow down or topdress treatment	Corn Plants per acre expected yields 10,000 60 bu.	14,000 80 bu.	18,000 100 bu.	Sugar beets 18 tons	Small grain	Late potatoes 300 cwt.	Beans, soy-beans 25 bu.
Legumes and 8 tons of manure per acre	5	5	10	10	10	25	10
Legumes -- no manure	10	10	40	20	10	55	10
8 tons of manure per acre	25	50	80	60	30	95	20
No legumes -- no manure	55	80	110	90	50	125	40

*Add 20% nitrogen to recommendations if soils are very low in organic matter. Subtract 20% if soils are high in organic matter (dark-colored).

Most calculations assume 70 pounds of nitrogen from a good legume sod and 4 pounds for each ton of manure. To determine fertilizer requirements, subtract these additions from "no legume--no manure" crop requirements, eg., if 100-bushel corn is desired on legume sod, use 40 pounds of nitrogen (110-70-40).

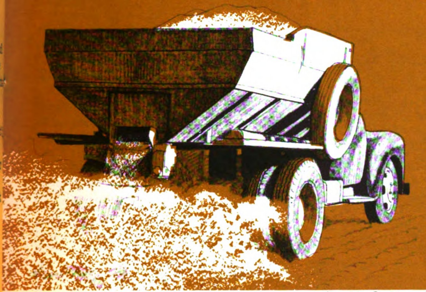
Purchase nitrogen on the basis of cost per pound of actual nitrogen and convenience of application. For the amounts of common nitrogen carriers required for a given amount of nitrogen, see Table 8. Each pound of nitrogen used may require 2 to 6 pounds of limestone to neutralize its residual acidity, so remember to check the lime requirement of your soil every 3 to 5 years.

Table 8. Pounds of different nitrogen fertilizers to use.

Carrier and percent N	Pounds of N desired 20	30	50	70	90	110
Ammonium sulfate, 21%	95	145	240	335	432	528
Ammonium nitrate, 33%	60	90	150	210	270	330
Synthetic urea, 45%	45	70	115	160	200	245
Anhydrous ammonia, 82%	25	40	65	90	115	145
Nitrogen solutions*	Pounds of N desired/percent N in carrier x 100 = pounds of carrier to use.					

*Nitrogen solutions will vary in N content. Check with your supplier.

Micronutrients. Many soils in east central Michigan, such as the Wisner and Essexville series, contain free lime in the plow layer. This excess lime in the soil makes some elements (Mn, Fe, Bo, Zn) insoluble and unavailable to some plants. Thus, oats, beans, soybeans, potatoes, sudan grass, sugar beets and spinach commonly respond to manganese mixed with fertilizer applied at planting time on these soils. Wheat, barley and corn may respond to manganese but not as frequently. Sugar beets often need boron if grown on soils with a pH above 6.5. Corn and beans commonly respond to zinc on these soils. See Extension Bulletin E-159 for further information on micronutrient deficiencies in Michigan soils and how to correct them. The acidity or pH of the soil is a valuable guide in micronutrient applications, particularly on organic soils, i.e. M soil management groups.



LIME
FOR MICHIGAN SOILS

COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY

Extension Bulletin 471, December 1964
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AGRICULTURAL LIMING MATERIALS, commonly called lime, are calcium and magnesium materials applied to agricultural soils to make them less acid.

Need for Lime in Michigan

About two-thirds of Michigan's cropland — 8 to 11 million acres — needs occasional liming. In general, Michigan farmers could profitably use 1½ million tons of agricultural limestone each year. The average annual use of limestone is now less than ½ million tons.

Long-time experiments conducted in Michigan indicate that agricultural lime applied according to soil test results will return at least \$5 to \$10 for every dollar spent for lime delivered and spread.

Benefits of Liming

Benefits of liming acid soils to modify their acidity can usually be attributed to some of the following factors:

1. Liming reduces harmful concentrations of aluminum, manganese and iron.
2. Liming increases the availability of phosphorus, molybdenum, and magnesium to cultivated crops.
3. All liming materials supply calcium. Dolomitic materials supply both calcium and magnesium. Both are essential elements for plant growth.
4. Liming promotes favorable microbial activity which results in increased release of organic nitrogen and decreased loss of gaseous nitrogen from the soil.
5. Liming promotes better soil structure and tilth — due partly to increased microbial action, partly to increased crop residue from higher crop yields, and partly to chemical effects of decreasing hydrogen ion concentration and increasing calcium and magnesium ion concentrations.

The effects of the degree of soil acidity (or pH, which is defined later) on the availability of plant nutrients in the soil are shown in Figure 1, page 2.

Most of the harmful effects reported from overliming mineral soils are due to decreased availability of certain nutrients — particularly manganese and zinc. As given in Table 1, crops vary in their needs for high lime levels or in their tolerance for soil acidity. Some plants require strongly acid soils for optimum growth.

What Is Soil Acidity?

Soils are acid because of hydrogen in the soil solution and on the surfaces of clay and organic matter particles that make up the soil. The soil solution is the soil water in which various chemical substances are dissolved. Hydrogen is present in it as *positively-charged* particles or ions. This is called *active hydrogen.* The degree of soil acidity, known as pH, is a measure of the *active hydrogen* in the soil solution. A value below pH 7.0 is acid; pH 7 is neutral; above 7.0 is alkaline.

The amount or concentration of *active hydrogen* in the soil solution is dependent on the amount of hydrogen held by the *negatively-charged* soil particles of clay and organic matter. Hydrogen ions on the surfaces of these particles are known as *exchangeable* ions because they can be readily replaced by other positively-charged ions such as calcium, magnesium or potassium. They represent *potential acidity.*

Many acid Michigan soils also contain considerable amounts of positively-charged aluminum ions. When the soil is limed, these ions react chemically with the soil water to produce hydrogen ions. This aluminum is another source of potential acidity.

Measurements of soil pH reflect only the *active*

**This bulletin is a revision of Extension Folder F-279, of the same title, by E. D. Longnecker, Extension Specialist in Soils, retired.*

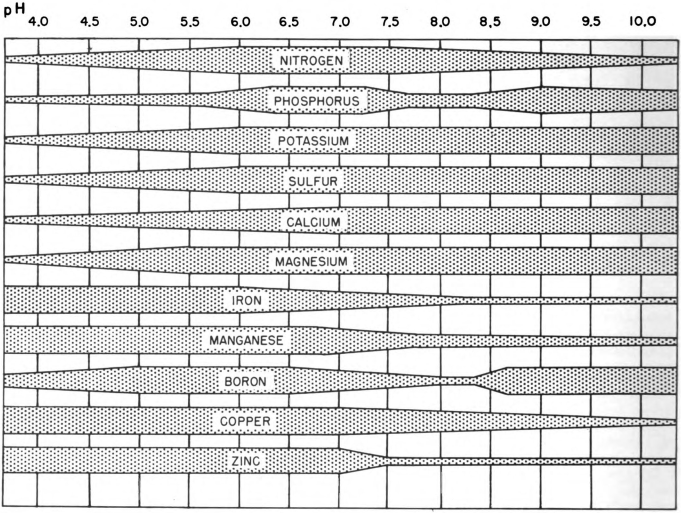

Fig. 1. — The general relation of pH to the availability of plant nutrients in the soil: the wider the bar, the more available is the nutrient. *(Adapted from Emil Truog, USDA Yearbook of Agriculture, 1943-47)*

Table I. Permissible soil pH ranges for various crops growing on mineral soils.

On organic soils (peat and muck) a pH of 5.5 to 6.0 is most satisfactory. For the most efficient fertilizer utilization and the most effective microbial action on mineral soils, a pH from 6.5 to 7.0 is desirable.

LEAST ACID TOLERANT	
Alfalfa	6.3 to 7.8
Asparagus	6.0 to 8.0
Barley	6.5 to 7.8
Beans	6.0 to 7.5
Peas	6.0 to 7.5
Red Clover	6.0 to 7.5
Soy Beans	6.0 to 7.0
Sugar Beets	6.0 to 7.5
Sweet Clover	6.5 to 7.8

MEDIUM ACID TOLERANT	
Corn	5.5 to 7.5
Grasses	5.5 to 7.5
Trefoil	5.5 to 7.0
Wheat	5.5 to 7.0

MORE ACID TOLERANT	
Buckwheat	5.0 to 7.0
Oats	5.0 to 7.0
Potatoes	5.2 to 6.5
Raspberries	5.0 to 7.0
Rye	5.0 to 7.0
Strawberries	5.0 to 6.5
Vetch	5.0 to 7.0

STRONGLY ACID SOILS REQUIRED	
Blueberries	4.0 to 5.1
Cranberries	4.2 to 5.0

hydrogen; they do not measure the much greater amounts of exchangeable hydrogen and aluminum — *the potential* acidity — held on the soil particles. Nevertheless, enough liming material must be applied to neutralize both the active and the potential acidity.

The pH of most Michigan soils is between 4.8 and 7.8. Practically all field crops grown on mineral soils in Michigan yield best on slightly acid to neutral soils — pH 6.5 to 7.0. On organic soils, the optimum pH is usually 5.5 to 6.0.

More lime is needed on heavy-textured acid soils than on light-textured acid soils because the heavier soils contain more exchangeable hydrogen and aluminum. For the same reason, soils high in organic matter need more lime than those low in organic matter.

Effectiveness of Lime Materials

In comparing the ability of liming materials to neutralize soil acidity (assuming all of the lime to be immediately effective) it becomes necessary to establish a standard. Since calcium carbonate is the most common ingredient in limestone, it is used as the standard of comparison.

Pure calcium carbonate is given a "neutralizing value" of 100. A calcic limestone consisting of 98% calcium carbonate, 1% clay and 1% sand has a neutralizing value (N.V.) of 98.

The N.V. of liming materials varies above or below "100" as their ability to neutralize acidity varies from that of calcium carbonate.

The expression "calcium carbonate equivalent" means practically the same as "neutralizing value" except that it is an expression of weight. We say that a cubic yard of marl contains a certain weight of "calcium carbonate equivalent" such as 1,240 pounds. The neutralizing values of various liming materials used in Michigan are given in Table 2.

Table 2. Neutralizing value (per cent calcium carbonate equivalent) of various liming materials.

MATERIAL	Neutralizing Value
Calcium carbonate (pure)	100
Magnesium carbonate (pure)	119
Calcium hydrate (pure)	135
Magnesium hydrate (pure)	172
Calcic limestone	less than 100
Dolomitic limestone	less than 108
Calcic hydrated lime	less than 135
Dolomitic hydrated lime	less than 170

Measuring Lime Needs

Measurements of soil pH, as made in the county soil testing laboratories, are used to determine if a soil should be limed. Lime needs can then be estimated from Table 3 on the basis of soil pH and soil texture.

In the state soil-testing laboratory at Michigan State University, a lime-requirement test is made in which both active hydrogen, or pH, and exchangeable hydrogen and aluminum, or potential acidity, are measured. This gives a more precise determination of lime requirement than the estimates made from soil pH and soil texture. However, satisfactory results are usually obtained from Table 3; any errors in lime recommendations usually result in underliming rather than overliming, so that additional lime may be applied after the soil is retested.

Lime recommendations made in either the state or county laboratories are in terms of the amount of ground limestone, with a *neutralizing value of 90%,* required to raise the pH of a *6⅔-inch plow layer* to *pH 6.5.*

From fields on which alfalfa is to be grown, a pH value between 6.8 and 7.0 is desirable; consequently, the recommendation from Table 3 should be *increased approximately one ton per acre when alfalfa is to be grown.* For some crops where lower pH values may be desirable, the recommendations can be decreased accordingly.

Limestones sold in Michigan usually range from 80 to 103% calcium carbonate equivalent, so the lime recommendations given in Table 3 from the central soil-testing laboratory should be adjusted for liming materials with neutralizing values different from 90. Figure 2 can be used for this purpose.

Liming rates given in Table 3 refer to a plow layer of 6⅔ inches. With the advent of larger tractors and plows, many farmers regularly plow to a depth of 10 to 12 inches. Consequently, heavier lime applications will be necessary to reach the desired pH levels. Recommendations derived from Table 3 (and Figure 2) can readily be converted for deeper plowing depths by using Figure 3. Examples of liming recommendations developed by using Table 3 and Figures 2 and 3 are given in Table 4.

Magnesium Needs in Michigan

Magnesium deficiency may occur in acid soils that have a sandy loam, loamy sand, or sand plow layer with a subsoil as coarse or coarser in texture than the plow layer, and in similar soils limed with calcic limestone or marl. Responsive crops are cauliflower, muskmelons, potatoes, peas, oats, wheat and rye. Dolomitic limestone should be applied to acid sandy soils which have less than 75 pounds of exchangeable magnesium per acre, as measured in the state laboratory.

Table 3. Tons of limestone to raise the pH of a 6-2/3-inch plow layer of different soils to pH 6.5.

Texture of plow layer	Soil Management Group	pH Range 4.5 to 4.9	5.0 to 5.4	5.5 to 5.9	6.0 to 6.4
		Tons of lime recommended*			
Clay and silty clay	1	6	5	4	2½
Clay loams or loams	2	5	4	3	2
Sandy loams	3	4	3	2½	1½**
Loamy sands	4	3	2½	2	1**
Sands	5	2½	2	1½**	½**

*Lime recommendations based on a liming material having 25 per cent passing through a 100-mesh sieve and having a neutralizing value of 90 per cent.

**It is preferable to recommend 2 tons per acre so as to obtain uniform application and to justify the expense of application.

Table 4. — Examples of lime recommendations developed using Table 3 and Figures 2 and 3.

pH	Texture	Alfalfa to be grown*	Neutralizing Value of Lime	Plow Depth (inches) 6⅔	9	12
				Tons of Lime		
5.5	Sandy loam	Yes*	90	3½	4½	6
5.5	Sandy loam	No	90	2½	3½	4½
5.6	Loamy sand	Yes*	105	2½	3½	4½
6.2	Loam	No	70	2½	3½	4½
4.8	Sandy loam	Yes*	80	5½**	7½**	10**
5.7	Clay loam	Yes*	103	3½	4½	6**

*When alfalfa is to be grown, the rate of application should be increased approximately 1 ton.

**One-half of lime should be disked in prior to plowing and one-half after plowing.

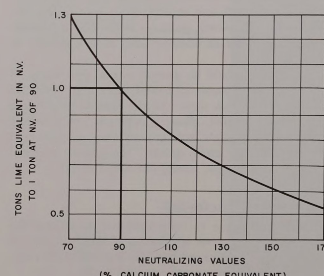

Fig. 2. — Conversion chart to determine amounts of limestone of various neutralizing value (N.V.) that are equivalent to 1 ton lime with N.V. of 90.

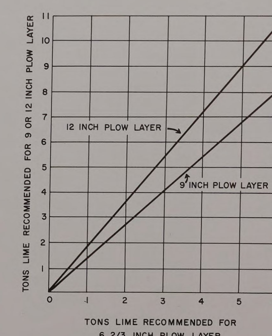

Fig. 3. — Diagram to convert recommendations made for a 6⅔-inch plow layer to recommendations for a 9- or 12-inch plow layer.

Kinds of Lime

In chemical terms, agricultural lime includes the oxide, the hydrate, and the carbonate of calcium or calcium and magnesium. Practically no oxide or burnt lime is used in Michigan. Hydrated lime makes up about 1%, calcic limestone 28%, dolomitic limestone 38%, marl and calcareous tufa 31%, and lime refuse from various local industries approximately 2% of the the agricultural lime now used in Michigan.

Calcic Limestone

Calcic limestone, sometimes called high-calcium limestone or calcitic limestone, is limestone containing less than 5% magnesium carbonate. With the exception of the limestone quarried in Monroe County, most of the agricultural limestone produced in the lower peninsula of Michigan is calcic limestone.

Dolomitic Limestone

Dolomitic limestone contains appreciable quantities of magnesium carbonate. That being marketed in Michigan contains from 15% to 45% magnesium carbonate, the remaining 85% to 55% being largely calcium carbonate. Practically all of the agricultural hydrate being used in Michigan is made from dolomitic limestone and is called dolomitic hydrate.

Magnesium in Lime

Magnesium in lime raises its neutralizing value because an ion of magnesium is lighter than an ion of calcium, but can replace the same amount of hydrogen from the soil.

Marl

Marl and refuse limes are satisfactory liming materials if applied in conformity with their lime contents and if spread evenly. Many of these materials have settled out of water charged with lime and are very fine in texture.

Under the Michigan lime law, marl and refuse limes are sold and guaranteed on the basis of the number of pounds of "calcium carbonate equivalent" per cubic yard. (This term is explained in detail in the section on "effectiveness.") Michigan marls average about 3.5% magnesium carbonate.

Because of their variability, marl and refuse lime are generally applied on the basis of two cubic yards per ton of limestone. More than two-thirds of the marl now being applied tests between 1200 and 1800 pounds calcium carbonate equivalent per cubic yard. This means that the actual liming rate is higher than recommended when marl is applied on the basis of two cubic yards per ton of limestone.

Rate of Reaction of Lime in the Soil

Limestones from various sources react at different rates; almost all dolomitic limestones are harder than calcic limestones and consequently react more slowly in the soil. In general, differences between sources of limestone are not great enough to warrant the preferential use of one source of limestone rather than some other source, except when dolomite is used to supply magnesium as well as raise the soil pH.

Methods of Applying Lime

The equipment used in spreading is not important as long as it spreads the lime uniformly and covers every square foot of the field area evenly. Lime will be distributed more evenly by disking and harrowing the soil thoroughly after spreading and before plowing.

If possible, lime should be applied and worked into the plow layer one year in advance of high lime-requirement crops. When heavy applications of lime (in excess of 5 tons per acre) are needed on strongly-acid soils that are to be plowed deeper than six or seven inches, half of the lime should be worked into the surface soil before plowing, and the other half worked in after plowing. Since lime moves very slowly in the soil, this will result in more even distribution throughout the entire plow layer.

Fineness of Grinding

The finer limestone is ground, the more quickly it will react in the soil.

Research data indicates that particles larger than 8-mesh (about ⅛ inch in size) have very little effect on the soil. However, particles in the 50- to 60-mesh range are about as effective after 6 to 9 months as finer materials.

Limestone should be ground so that practically all of the material passes an 8-mesh sieve and about 25% passes a 100-mesh sieve. All the fines from grinding should be retained. Finer grinding is not generally necessary; although lime ground more finely would react somewhat more quickly, the coarser material would have a longer lasting effect on the soil.

Lime Losses from the Soil

It is impossible to state definitely how long the benefits from a given application of lime will last. It is advisable to retest soil from the limed field after two to four years to measure the change in pH.

Lime is lost from the soil by cropping and pasturing, by leaching (drainage through the subsoil), and by wind and water erosion. Keeping a growing crop on land as much as possible will retard leaching losses

and erosion. Legumes remove more calcium and magnesium than other crops.

Possibly 200 to 300 pounds of lime are lost per acre of top soil in Michigan each year. How frequently you should lime your soil can only be learned by testing representative samples of soil.

Effect of Fertilizers on Soil Acidity

Present fertilizer practices increase crop yields, and thus increase the removal of calcium and magnesium from the soil. In addition, many fertilizers, particularly the nitrogen carriers, leave an acidic residue in the soil. Table 5 gives the amount of lime (as pounds of calcium carbonate) required to neutralize the acids formed from one pound of nitrogen from each of the various nitrogen fertilizers. Over a period of years, these fertilizers can markedly decrease the soil pH.

While the differences between these sources of nitrogen are not great enough to justify selection of any particular source (lime is much cheaper than nitrogen) these effects should be recognized so that lime can be applied when needed.

Table 5. Pounds of lime (calcium carbonate) required to neutralize the acidity produced per pound of nitrogen (N).

Nitrogen Carrier	Pounds Calcium Carbonate
Ammonium nitrate	1.8
Ammonium sulfate	5.5
Anhydrous ammonia	1.8
Urea	1.9

The Michigan Lime Law

The Michigan Lime Law is simply a labelling act. It requires that all agricultural liming materials offered for sale within Michigan be licensed with the Michigan Department of Agriculture each year.

With each sale of lime the purchaser is to be provided with a written statement giving the name of producer, his address, the name of the material, the net weight of the lime, the neutralizing value, and the percentage of the lime passing an 8-, 60- and 100-mesh screen.

For marl and refuse limes, the volume (cubic yards) and test expressed as pounds of calcium carbonate equivalent per cubic yard are to be stated in place of neutralizing value and screen test.

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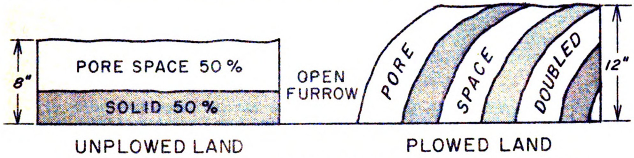
Cooperative extension work in agriculture and home economics. Michigan State University and the U. S. Department of Agriculture cooperating. N. P. Ralston Director, Cooperative Extension Service, Michigan State University, East Lansing. Printed and distributed under Acts of Congress, May 8 and June 30, 1914.
1P1R-11:64-20M-HK

MINIMUM TILLAGE

Profitable farming requires a gross return from the sales of produce that exceeds the costs of production. A higher net return may result from increasing the amount produced per unit of expenditure or decreasing the costs per unit of production. Minimum tillage is the least tillage or seedbed preparation necessary to insure rapid seed germination, a good stand, and good crop yields. This practice decreases production costs to a minimum without decreasing production. It can result in savings of $3.00 to $7.00 per acre and valuable time during spring work. Ideally it should be a once-over operation and should leave the soil as porous as possible so that water and air can penetrate and provide good soil tilth.



FRESHLY PLOWED CLAY LOAMS MAY CONTAIN TWICE THE PORE SPACE THEY DO BEFORE PLOWING.

This management practice commonly results in less runoff, less erosion, more water storage for the crop, less weed growth early in the season, and better pest control. For all crops, minimum tillage involves delay of plowing until the soil is in good condition--not too wet, and adjusting the plow to turn a good clean furrow with no trash showing. A fitting tool that has a slight leveling and firming action should be trailed behind the plow especially on sand, loamy sand, or sandy loam soil groups. A section of a harrow, a rotary hoe, a cultipacker, or a plow packer are all good. The remaining tillage operations vary somewhat with the crops as follows:

Corn should be planted the day the field is plowed. The planter may be trailed in the tractor wheel marks if a narrow-guage tractor is available; otherwise, weight the planter or the press wheels to give contact of the seed with the surrounding soil. On sloping land, plant across the slope.

Spring grain should be planted the day the field is plowed. It is sometimes desirable to fill in the tractor wheel marks in front of the drill. For this purpose, a spike tooth dragged below the tongue of the drill is satisfactory. Some people have put dual wheels on the grain drill to add supporting surface. If the drill is not equipped with press wheels, pull a roller or cultipacker behind the drill.

Sugar beets should be planted with the beet drill the same day the field is plowed.

Potatoes may require other tillage methods and chemicals to control quack grass and other weeds.

Beans should be planted before the soil becomes too dry. If weeds have sprouted after plowing, drag once and plant without further tillage. Consider the suggestions under spring grains for adapting the drill to loose seedbeds.

Perhaps as experience increases, the minimum tillage operations can be made more specific for the different soil management groups. To date, it has been successful in experiments on clay loams and coarser soil groups. Some specific suggestions will be found in the leaflet for each soil management group.

EROSION CONTROL: PRINCIPLES, PRACTICES AND RECOMMENDED CROPPING SYSTEMS

Research is continuing on solution of the complex problem of erosion control on various soils with alternative cropping and management systems in different localities. Recently, largely through the efforts of the Agricultural Research Service of the U.S.D.A., cooperating with the State Agricultural Experiment Stations and the Soil Conservation Service of the U.S.D.A., a universal equation for predicting rainfall erosion losses has been developed and tested. The resulting recommendations are being presented this year for the first time in Michigan.

This universal equation is: A = RKLSPC. A is the average annual soil loss in tons per acre predicted by the equation; R is the rainfall index; K is the soil erodibility factor; LS is the length and steepness of slope factor; P is the supporting conservation practice factor for terracing, stripcropping, or contouring; and C is the cropping and management factor.

In using this equation, the estimated allowable annual soil loss, T, is commonly substituted for A and the equation is solved for C as follows: $\frac{T}{RKLSP} = C$.

The Soil Conservation Service personnel of the U. S. Department of Agriculture have estimated T and K values for the various soils based upon experience with the soils when managed in various ways and a few measurements available from the Agricultural Research Service for K.

In this brief presentation of some representative cropping and management recommendations for the various soil groups, and their slope and erosion subdivisions, the estimated T and K values of the U. S. Department of Agriculture for each soil group and a rainfall factor of 100 are used. A slope length of 200 feet and a percent slope in the middle of the range of each slope class are assumed*. For conditions that vary appreciably from these assumptions, it would be well to consult the local Soil Conservationist for more precise recommendations tailored to the soil in each of your fields. We particularly urge this action if you want to use the areas more intensively than indicated in the tables, or where you note excessive soil losses with the use of cropping systems similar to those recommended in the tables.

The variations in slope class and degree of erosion are tabulated on the left hand side of the table for each soil group that accompanies this general discussion. The table for the 1.5a and 1.5b soil management groups is included here as an illustration. The various conservation practices are listed across the top of each such table. The maximum "C" values recommended are listed in each table for any combination of soil group, slope class, erosion class and conservation practice. These tables appear under the heading Erosion Control in the management leaflet for each group of soils.

Any cropping system, with the listed associated management practices and the given expected crop yields, that have an equal or lower "C" value than those recommended in the tables for each of the soil groups are considered

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*Erosion is more rapid on longer slopes and on steeper slopes. The affect of the steepness is apparent in the tables since the values cited for the A, B, C, D, and E slopes correspond to values calculated for 2, 4, 9, 15 and 21% slopes, respectively. You can interpolate for approximate intermediate values. Slopes 100, 200, 300, and 400 feet long permit C values about 1.5, 1.0, 0.8 and 0.7 times those cited in the tables.

satisfactory for keeping soil loss within allowable limits. These alternatives can be located in Table 4A.

If you wish to test a given cropping system,* you can find representative systems listed alphabetically in Table 4B with their C_1 values. These C_1 values appear in numerical order in the left-hand column of Table 4A. Other C values that apply to the management practices and expected yields listed across the top of Table 4A can be located there for comparison with the maximum recommended C values cited for each soil management unit in the tables for the various soil management groups.

Remember the best protection for the soil from excessive erosion is a vigorous, complete and continuous vegetative cover. The effect of vegetative vigor is evident in the lower expected relative soil losses where crop yields are higher within a given cropping and management system (C_1, C_3 and C_6 or C_5) in Table 4A. For example, in the C_1 column continuous corn at a yield of 75+ bu. would result in .26 (or 26%) of the soil loss from continuous fallow while continuous corn with a yield of 40 to 59 bu. would result in 39% of the soil loss from continuous fallow. Good meadow crops or forest furnish a complete and continuous cover and afford the greatest protection for the soil. Thus, the meadow crops have the smallest relative soil losses cited in Table 4A.

With any given crop yield, minimum tillage and leaving crop residues on the land surface until preparation of the land for the next crop each decreases the expected soil losses (C_3 or C_6) compared to conventional tillage and removal of crop residues (C_5). A combination of minimum tillage and leaving crop residues (C_1) is even more effective than either practice alone (C_3 or C_6), as shown in Table 4A.

Contour tillage, strip cropping and terracing are conservation practices that may be needed or helpful in decreasing expected relative soil losses. These are illustrated by the "Maximum C Values of Cropping Systems that will Control Erosion on Soils of the 1.5a and 1.5b Management Groups" in Table 5. Consequently cropping systems with greater expected relative erosion losses can be used with those conservation practices than with up and down hill cultivation. An apparent exception to this rule is evident on the A and B slopes for contour strip cropping in Table 5, but this is due to the fact that this system requires alternation of strips of row crops with small grain and/or meadow crops. The least protective system of this kind is RROM which has a maximum C values of 0.24 under C_5 in Table 4A.

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*Each cropping system is abbreviated in this listing by substituting a letter for each crop. (M = meadow or hay, O = spring grain, R = row crop, and W = winter grain. A small x indicates a cover crop.)

These letters are arranged in the order that the crops appear on each field beginning with the row crop (R) if one is present in the cropping system. If no row crop is present, the first one cited is the first small grain crop (O or W). If neither a row crop nor a small grain crop is involved, the meadow crop (M) is cited first. A small grain or row crop with a cover crop (O_x, W_x or R_x) would follow a small grain or row crop without a cover crop (O, W or R) in the alphabetical list. Thus, a cropping system of corn, oats, wheat and 3 years of alfalfa-brome would be ROWMMM, while a system of wheat with 2 years of alfalfa-brome would be WMM and would appear later in the alphabetical list.

Table 4A. C values for representative cropping systems in numerical order of their C_1 values. The figures below represent the relative average soil losses expected with these cropping systems compared to continuous fallow, when the indicated management practices cited are used, and the indicated average yield levels are expected.

Cropping system / Yields of:	Management System and Yield Levels: Residues* left, min. till.=C_1			Conv. till.+residues=C_3 or min. till.--no residues=C_6			Conv. till. and no residues=C_5		
corn(bu/A.) →	40-59	60-74	75+	40-59	60-74	75+	40-59	60-74	75+
hay (t/A.) →	1-2	2-3	3+	1-2	2-3	3+	1-2	2-3	3+
R(cont. corn)	.39	.32	.26	.51	.47	.42	.58	.56	.52
RRRO$_x$	.29	.24	.20	.37	.34	.31	.43	.41	.37
RRO$_x$	.26	.22	.19	.33	.29	.26	.38	.35	.32
R$_x$R$_x$	.25	.20	.18	.38	.34	.31	--	.46	.44
R$_x$R$_x$RO$_x$	.23	.19	.17	.31	.28	.26	.38	.36	.33
R$_x$RO$_x$	.23	.19	.17	.29	.26	.23	.34	.32	.29
RRROM	.20	.16	.13	.25	.21	.19	.30	.28	.24
RO$_x$	.19	.17	.15	.24	.21	.19	.28	.25	.22
R$_x$R$_x$ROM	.15	.13	.11	.22	.19	.17	.27	.25	.22
RROM	.15	.12	.10	.20	.16	.14	.24	.21	.18
R$_x$ROM	.13	.11	.09	.18	.15	.13	.21	.19	.17
RCWM	.13	.12	.11	.15	.14	.12	.18	.17	.15
ROMW$_x$	.11	.10	.095	.14	.13	.12	.16	.15	.13
RROMM	.12	.094	.079	.16	.13	.11	.19	.17	.15
RROMMM	.10	.08	.067	.13	.11	.097	.16	.14	.12
ROM	.09	.078	.06	.12	.097	.081	.14	.12	.10
RCWMMM	.088	.081	.071	.105	.097	.085	.12	.11	.10
ROMMMW$_x$	.078	.07	.064	.097	.085	.076	.11	.10	.088
ROMM	.07	.06	.047	.087	.075	.063	.11	.092	.076
WOMM	.058	.057	.048	.058	.057	.048	.094	.091	.084
ROMMM	.057	.049	.038	.071	.065	.051	.087	.074	.062
WM	.045	.045	.038	.045	.045	.038	--	--	--
WMM	.032	.031	.027	.032	.031	.027	--	--	--
OMM	.025	.024	.021	.025	.024	.021	--	--	--
M-Alf.		.02							
M-Red Cl.		.015							
M-Alf. Brome	.006		.004						

*Residues left includes corn and soybeans where residues equal 2 or more tons per acre.

Corn for silage, potatoes, field beans and vegetable crops are considered crops with no residues left.

Table 4B. C_1 values or average erosion losses under various cropping systems relative to continuous fallow. (These values assume that: residues are returned, minimum tillage is used, and average yields expected are, corn = 40-59 bu/A. and hay = 1-2 T/A. See table 4A for "C" values of these cropping systems with other management practices and yield expectations.)

Cropping systems* (alphabetically arranged)	C_1 value	Cropping system	C_1 value	Cropping system	C_1 value
M(alfalfa)	0.020	ROMM	0.07	RROMMM	0.10
M(alfalfa-brome)	0.006	ROMMM	0.057	RRCWM RRRO$_x$	0.29
M(red clover)	0.015	ROMMMW$_x$	0.078	R_xR_xRO$_x$	0.23
O	0.22	ROMW$_x$ ROWM	0.11 0.13	RRROM R_xR_xROM	0.20 0.15
OMM	.025	ROWMMM	0.088	RWMM	0.15
R(corn or soybeans)	0.39				
R(sugar beets, n. beans, potatoes)	0.51(C_3)**	R_xR_x	0.25		
R_x	0.23	RRO$_x$ R_xRO$_x$	0.26 0.23	WM WMM	0.045 0.032
RO$_x$	0.19	RROM R_xROM	0.15 0.13	WOMM	0.058
ROM	0.09	RROMM	0.12		

*M = meadow or hay crop; O = spring grain; R = row crop; W = winter grain; x = cover crop.

**Crop residues are not sufficient in amount for the C_1 management level.

Table 5. Maximum C values* of cropping systems recommended for soils of the 1.5a and 1.5b management groups with specified slope classes, erosion classes, and erosion control practices. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the cropping systems in Table 4A. (See Group 2a and 2b for other information on these soil groups.)

		Erosion control practices			
Slope class	Erosion classes	Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.20	0.38	0.24	0.58
B	0,1,2	0.12	0.23	0.24	0.37
	3	0.080	0.15	0.24	0.28
C	1,2	0.048	0.080	0.16	0.13
	3	0.032	0.053	0.11	0.090
D	1,2	0.019	0.024	0.048	Not
	3	0.013	0.016	0.032	recommended
E+	1,2,3	Permanent vegetation, grass or trees			

*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for the RROM cropping system, or 0.11 for the ROMM cropping system.

Table 6 indicates the strip width, maximum slope lengths and terrace spacings recommended on different slope groups with strip cropping and terracing practices.

Table 6. Variations in width of row crop or grain strips, in strip cropped areas, maximum length of slopes where strip cropping is recommended for control of water erosion*, and terrace spacings for use on slopes of different gradients.

Slope class	Percent slope	Strip width	Strip cropping--maximum length**	Terrace spacings
B	2.1- 6.0	100-88 ft.	400 ft.	170-110 ft.
C	6.1-12.0	88-74 "	400 "	100-86 "
D	12.1-18.0	74-60 "	300 "	Not
E	18.1-24.0	60-50 "	200 "	recommended

*For reduction of wind erosion these strips should not be more than 132 feet in width.

**Length of slope is the distance from a ridge or crest where runoff begins to the point where it enters a well-defined channel or to a point where the slope decreases to the extent that deposition begins.

SOIL MANAGEMENT GROUPS Oa, Ob, Oc and 1a, 1b, 1c soils

Examples of 1a, 1b, 1c soils

1a

Brown: granular silt loam

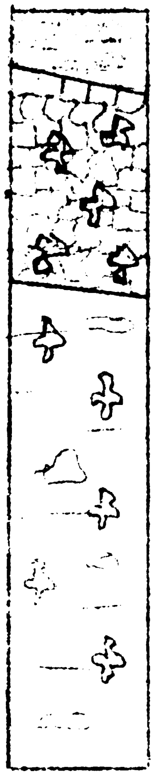
Yellowish brown silt loam

Dark yellowish brown, mottled: blocky silty clay or clay

Dark brown distinctly mottled calcareous silty clay or clay, glacial till

St. Clair

1b



Dark grayish brown weak granular silt loam

Grayish brown, with distinct mottles: blocky: silty clay loam to clay.

Grayish brown, mottled calcareous, silty clay loam to clay, glacial till

Nappanee

1c

Very dark gra weak granular clay

Dark gray to grayish brown distinctly mottled: blocky: clay

Gray with distinct mott calcareous cl occasional pe bles

Hoytville

Fill in the name and management unit for all soils in the above management groups th occur on your farm.

Management Unit	Soil Name

SOIL MANAGEMENT GROUPS Oa, Ob, Oc and 1a, 1b, 1c soils

Examples of 1a, 1b, 1c soils

1a

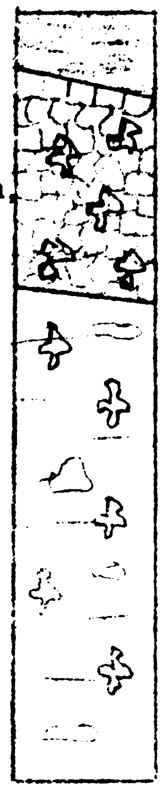
Brown: granular silt loam
Yellowish brown silt loam

Dark yellowish brown, mottled: blocky silty clay or clay

Dark brown distinctly mottled calcareous silty clay or clay, glacial till

St. Clair

1b



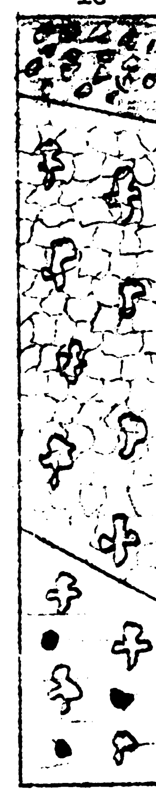
Dark grayish brown weak granular silt loam

Grayish brown, with distinct mottles: blocky: silty clay loam to clay.

Grayish brown, mottled calcareous, silty clay loam to clay, glacial till

Nappanee

1c



Very dark gra weak granular clay

Dark gray to grayish brown distinctly mottled: blocky: clay

Gray with distinct mott calcareous cl occasional pe bles

Hoytville

Fill in the name and management unit for all soils in the above management groups th occur on your farm.

Management Unit	Soil Name

GROUPS Oa, Ob, Oc -- See discussion below.

GROUPS 1a, 1b, 1c

Description: These soils were all developed in limy clay or silty clay materials. The 1a group has light colored surfaces and bright colored subsoils. They occur on nearly level to steep areas with low water tables. The 1b group has moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. The 1c group has dark colored surfaces and grey subsoils. They occur on nearly level to depressional areas and are nearly neutral to alkaline in reaction. All three groups have moderate readily available moisture holding capacities and are very slowly permeable. Clay soils, containing more than 55% clay, are now being designated as Oa, Ob, and Oc soil groups. See Erosion Control, below.

Management problems: Group 1a -- (1) maintaining good tilth and organic matter content; (2) control of water erosion; (3) acid, unless limed; (4) need fertilization.

Group 1b -- (1) maintaining good tilth and organic matter content; (2) inadequate drainage; (3) need fertilization, and (4) acid unless limed.

Group 1c -- (1) inadequate drainage; (2) maintaining good tilth and organic matter content; (3) need fertilization; (4) the Charity series is limy and boron or manganese may be needed.

Crop adaptations: Where topography and drainage are satisfactory, all common farm crops are fairly well adapted, except potatoes. Trees are seldom planted except on steep slopes or severely eroded areas where white pine, Austrian pine, ponderosa pine and white spruce are suitable. Reed canary grass does well on the undrained areas.

Drainage recommendations: Occasionally tile will be needed in the 1a group to intercept seepage on slopes. The soils in group 1b commonly require tile drainage for optimum crop yields. Unless artificial drainage has been supplied, it will be needed for crops on group 1c soils. Tile should be placed 2 to 4 rods apart and 3 to 4 feet deep in these soils where outlets are adequate. Tile should be covered with straw or other porous backfill material. They should be placed above seep spots on slopes at a depth of 3 to 4 feet or on impermeable layer when present but not less than 30 inches deep. Catch basins with sump pumps may be used where natural tile outlets are not available. Plowing in narrow lands (bedding) and leaving the dead furrows for surface drains also help to remove surface water.

Minimum tillage: The soils in management groups 1a, 1b, and 1c are so high in content of clay that extreme care must be taken to avoid puddling. Moisture content at time of plowing is very critical but when it is optimum, minimum tillage can be highly recommended. In fact, it is more important to avoid excess tillage on these soils than on those coarser in texture. We should define "excess" in this case as any tillage operation not actually needed to put the soil into the physical condition needed for satisfactory planting.

Be sure soil moisture content is sufficiently low that the furrows just turned from the moldboard will be loose and crumbly. If this is not the case, the chief objective in mold-board plowing has not been achieved. One should be sure, also, that the soil immediately below the furrow is not too wet or a tillage pan will develop. Fall plowing is commonly practiced to advantage.

Minimum tillage, conducted at optimum moisture content, is especially desirable for 1a soils. Erosion control is very important on these soils and minimum tillage is recognized as the best erosion control practice that can be applied to row crops.

Planting is usually facilitated by attaching a smoothing device behind the plow.

FERTILIZER RECOMMENDATIONS (for soil management groups 1a, 1b and 1c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS:	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa[2], alfalfa-brome[2], clover, and sweetclover	0+60+30	0+60+ 0	0+30+30	0+30+15
Alfalfa, after each harvest year[2]	0+50+50	0+50+25	0+25+50	0+25+25
Grass without a legume	50+25+25	50+25+10	50+0+25	50+0+0
Barley[3] or oats[3] with legume seeding	15+60+30	15+60+15	15+30+30	15+30+15
Barley[3] or oats[3,4] without legume seeding	20+40+20	20+40+20	20+20+20	20+20+20
Field beans[3,4]	12+50+25	12+50+12	12+25+25	12+25+12
Soybeans[3,4]	10+40+20	10+40+10	10+20+20	10+20+10
Sugar beets[3,4,5]	25+100+50	25+100+25	25+50+50	25+50+25
Wheat[3,4], rye[4]	15+60+30	15+60+15	15+30+30	15+30+15
Corn[4]	12+50+25	12+50+12	12+25+25	12+25+12

[2]Apply fertilizer containing 1/2 per cent boron if pH is above 6.5.
[3]Where pH is above 6.9, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be needed.
[5]Apply fertilizer containing 1/4 percent boron if pH is above 6.5.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grains will be about 30% less on severely eroded areas that can be cultivated.

For Southern Michigan

Crops	Soil management group 1a	1b	1c	Crops	Soil management group 1a	1b	1c
Corn (bu)	80	95	105	Barley (bu)	52	55	57
Field beans (bu)	23	23	25	Alfalfa (tons)	3.5	3.7	4.2
Soybeans (bu)	26	29	34	Mixed hay (tons)	2.2	2.4	2.7
Sugar beets (tons)	-	15	18	Pasture (cow days)	140	150	160
Wheat (bu)	40	45	50	Aspen (cords)	1.0	.65	-
Oats (bu)	70	77	82	White pine (bd.ft.)	165	-	-

Lime recommendations will be found in the section on Liming Michigan Soils.

Fertilizer placement recommendations for various crops will be found in the section on Soil Tests and Fertilization.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, and 5) proper timing of all cultural operations.

Erosion Control

Maximum C values* of cropping systems that will control erosion on soils of the Oa, Ob and Oc management groups with specified slope classes, erosion classes and conservation practices as indicated. Compare with the C values for cropping and management systems in Table 4A. See groups 1a, 1b and 1c for other information on these soil groups.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.15***	0.15***	0.15***	Not
B	0,1,2	0.100	0.15***	0.15***	recom-
C	1,2	0.030	0.045	0.090	mended
D+	1,2,3	Permanent cover, grass or trees			

Erosion Control

Maximum C values* of cropping systems recommended for soils of the 1a, 1b, and 1c management groups with specified slope classes, erosion classes, and erosion control practices. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the cropping systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.17	0.34	0.24	Not
B	0,1,2	0.10	0.20	0.24	recom-
	3	0.067	0.13	0.24	
C	1,2	0.040	0.066	0.13	mended
	3	0.027	0.044	0.088	
D	1,2	0.017	0.021	0.042	
	3	0.011	0.014	0.028	
E+	1,2,3	Permanent vegetation, grass or trees			

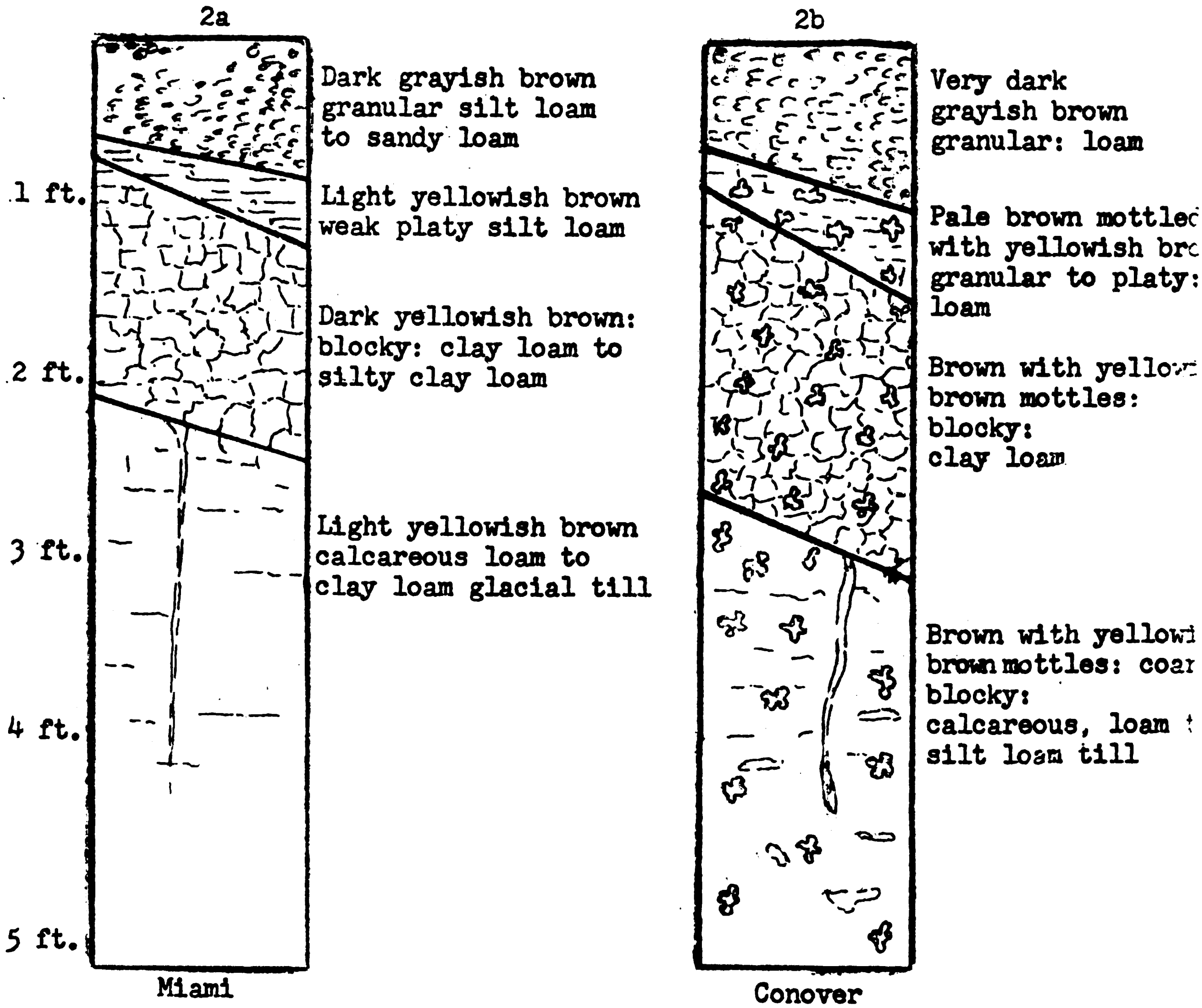
*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for RROM cropping system and 0.11 for the ROMM cropping system.

***Maintaining suitable structure of the plow layer is a major limiting factor on these soils. A sod crop every third or fourth year is recommended.

SOIL MANAGEMENT GROUPS 2a, 2b

Examples of 2a and 2b soils



Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

GROUPS 2a, 2b

Description: These soils were all developed in limy loam or clay loam materials. The 2a group has light colored surfaces and bright colored subsoils. They occur on nearly level to steep well drained areas with low water tables. The 2b group has moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Both groups have moderately high readily available moisture holding capacities, and are slowly permeable. The soils developed in clay loams are now being designated as the 1.5a and 1.5b groups and those developed in loam as the 2.5a and 2.5b groups. See Erosion Control, below.

Management problems: Group 2a (1) control of water erosion; (2) maintaining good structure and organic matter content; (3) acid unless limed, except for the Gagetown series; (4) need fertilization.

Group 2b - (1) maintaining good structure and organic matter content; (2) inadequate drainage; (3) need fertilization; and (4) acid unless limed.

Drainage recommendations: Soils in group 2b commonly require tile drainage for optimum crop yields. Occasionally, tile may be needed on inadequately drained spots in the 2a group or to intercept seepage on slopes. Tile should be placed 4 to 6 rods apart and 3 to 4 feet deep in these soils.

Crop adaptations: All common farm crops are well adapted where topography and drainage are satisfactory. Seldom planted to trees except on severely eroded or steep areas. White pine, Austrian pine, Norway spruce and ponderosa pine are suitable for that purpose. Alfalfa, red clover, and bromegrass are adapted pasture plants.

Minimum Tillage: Soils in management groups 2a and 2b are very well adapted to the principles of minimum tillage. They are intermediate in texture and under good management are possessive of fairly stable structure. When moisture content is ideal, and when, moldboard plowing is properly done, they crumble readily and have maximum pore space after plowing. The resulting plowed layer is then an ideal root bed.

Most of the series in these groups are on gentle to steep slopes. Accordingly the erosion control offered by minimum tillage is particularly valuable. Fall plowing is not advisable on these soils so the practice of plow-plant is especially recommended.

The use of a smoothing device behind the plow may facilitate planting.

Other production and conservation practices important in the success of a cropping system are: (1) use of certified seed of adapted varieties, (2) seed treatment with fungicides and insecticides, (3) control of weeds by cultivation or sprays, (4) return of crop residues to the soil, and (5) proper timing of all cultural operations.

FERTILIZER RECOMMENDATIONS (for soil management groups 2a and 2b) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS: ⇒	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY: ⇒	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa,[2] alfalfa-brome,[2] clover and sweet clover	0+80+40	0+80+20	0+40+40	0+40+20
Alfalfa after each harvest year[2]	0+50+100	0+50+50	0+25+100	0+25+50
Grass without a legume	50+25+25	50+25+0	50+0+25	50+0+0
Barley or oats with legume seeding	20+80+40	20+80+20	20+40+40	20+40+20
Barley [4] or oats [4] without legume seeding	30+60+30	30+60+30	30+30+30	30+30+30
Field beans [4]	12+50+25	12+50+12	12+25+25	12+25+12
Soybeans [4]	10+40+20	10+40+10	10+20+20	5+20+10
Wheat or rye with legume seeding	22+90+45	22+90+22	22+45+45	22+45+22
Wheat [4] or rye[4] without legume seeding	20+80+40	20+80+20	20+40+40	20+40+20
Sugar beets [4,5]	30+120+60	30+120+30	30+60+60	30+60+30
Potatoes[4]	40+160+160	40+160+80	40+80+160	40+80+80
Corn[4]	15+60+30	15+60+15	15+30+30	15+30+15

[2] Apply fertilizer containing ½ percent boron if pH is above 6.5. on 2a soils.

[4] Supplemental nitrogen may be needed.
[5] Apply fertilizer containing ½ percent boron if pH is above 6.5.

Crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grain crops will be about 20% less on severely eroded areas that can be cultivated.

For Southern Michigan

Crops		Soil management group 2a	2b	Crops		Soil management group 2a	2b
Corn	(bu)	90	100	Oats	(bu)	80	90
Corn silage	(tons)	17	19	Barley	(bu)	56	60
Field beans	(bu)	28	33	Alfalfa	(tons)	3.9	4.0
Soybeans	(bu)	28	33	Mixed hay	(tons)	2.4	2.7
Sugar beets	(tons)	16	18	Pasture	(cow days)	150	155
Potatoes	(cwts)	300		Aspen	(cords)	1.3	0.8
Wheat	(bu)	47	53	White pine	(bd.ft.)	300	--

Lime recommendations will be found in the section on Liming Michigan Soils.

Fertilizer placement recommendations for various crops will be found in the section on Soil Tests and Fertilization.

Erosion Control

Maximum C values* of cropping systems recommended for soils of the 1.5a and 1.5b management groups with specified slope classes, erosion classes, and erosion control practices. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the cropping systems in Table 4A. See Group 2a and 2b for other information on these soil groups.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.20	0.38	0.24	0.58
B	0,1,2	0.12	0.23	0.24	0.35
	3	0.080	0.16	0.24	0.28
C	1,2	0.048	0.080	0.16	0.11
	3	0.032	0.053	0.11	0.090
D	1,2	0.014	0.024	0.048	Not recommended
	3	0.010	0.016	0.032	
E+	1,2,3	Permanent vegetation, grass or trees			

Erosion Control

Maximum C values* of cropping systems recommended for soils of the 2.5a and 2.5b management groups with specified slope classes, erosion classes, and erosion control practices. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the cropping systems in Table 4A. See Group 2a and 2b for other information on these soil groups.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.23	0.45	0.24	0.60
B	0,1,2	0.13	0.27	0.24	0.40
	3	0.09	0.18	0.24	0.28
C	1,2	0.054	0.090	0.18	0.13
	3	0.036	0.060	0.12	0.090
D	1,2	0.022	0.027	0.054	Not recommended
	3	0.015	0.018	0.036	
E		Permanent vegetation, grass or trees			

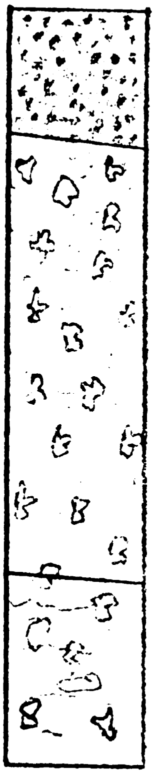
*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for the RROM cropping system and 0.11 for the ROMM cropping system.

SOIL MANAGEMENT GROUP 2c

Example of 2c soil

2c



Very dark grayish brown: granular silty clay loam

Yellowish brown with distinct mottles: blocky: clay loam to silty clay loam

Light olive brown, with distinct mottles calcareous loam

Brookston

Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

GROUP 2c

Description: These are dark colored, naturally poorly drained soils, that have been formed in loam to clay loam materials. They occur on nearly level to depressional areas. Their reaction is usually nearly neutral at the surface but the Wisner, Thomas, Tappan, and Whittemore series are limy. These soils are slowly permeable. They have moderate to moderately high readily available moisture holding capacities. These soils are naturally fertile. The soils developed in clay loams are now being designated the 1.5c group and those in loam as the 2.5c group.
Management problems: (1) inadequate drainage; (2) maintenance of organic matter content and good tilth; (3) fertility maintenance and micronutrient deficiencies (boron, manganese and possibly zinc) for some crops, particularly in limy members.

Crop adaptations: All common farm crops are well adapted if these soils have been adequately drained. Where undrained, these areas may be used for pasture. Reed canary grass is well adapted to such areas. Trees are seldom planted and because of the high water table in undrained areas, the yields of woodlands are generally low. A continuous row crop such as corn, with a green manure crop seeded at the last cultivation will maintain organic matter and good tilth on these soils.
Drainage recommendations: These soils need artificial drainage if crops are to be grown successfully. Tile drains should be spaced 4 rods apart and 3 to 4 feet deep. Where a natural outlet is not available, catch basins with sump pumps can be used. The effectiveness of the tile system will be improved by backfilling with straw, grass or surface soil.

Minimum tillage: Group 2c soils are easier to till than are those in groups 2a and 2b. This is largely because of higher organic matter and generally more uniform tile drainage. The better structure resulting from the organic matter makes them friable and granular. The furrows from the plow fall into granules as they are turned so it is easy to do a good smooth job of plowing. The range is soil moisture percentage at which soils plow satisfactorily is relatively wide on 2c soils.

Excess tillage is less harmful on these soils than on those finer in texture or lower in organic matter. This is partly because erosion is not severe as the soils are all practically level. Their high organic content gives them stable structure so they are not so easily compacted. Tillage costs money, however, so let's not waste it by useless, and perhaps harmful operations. Plow-plant should be the rule on these soils.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) application of fertilizers according to test as described on the next page, 4) control of weeds by cultivation or sprays, 5) return of crop residues to the soil, and 6) proper timing of all cultural operations.

FERTILIZER RECOMMENDATIONS (for soil management group 2c) in pounds per acre of nitrogen, N; Phosphate, P_2O_5 and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS:	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa,[2] alfalfa-brome,[2] clover, and sweetclover	0+80+40	0+80+20	0+40+40	0+40+20
Alfalfa, after each harvest year[2]	0+60+30	0+60+0	0+30+30	0+30+15
Grass without a legume	50+25+25	50+25+0	50+0+25	50+0+0
Barley[3] or oats[3] with legume seeding	20+80+40	20+80+20	20+40+40	20+40+20
Barley[3,4] or oats[3,4] without legume seeding	30+60+30	30+60+0	30+30+30	30+30+15
Field beans[3,4,6]	15+60+30	15+60+15	15+30+30	15+30+15
Soybeans[3,4]	12 +50+25	12+50+12	12+25+25	12+25+12
Wheat[3] or rye[4] with legume seeding	25+100+50	25+100+25	25+50+50	25+50+25
Wheat[3,4] or rye[4] without legume seeding	20+80+40	20+80+20	20+40+40	20+40+20
Sugar beets[3,4,5]	40+160+80	40+160+40	40+80+80	40+80+40
Corn[4,6]	20+80+40	20+80+20	20+40+40	20+40+20

[2]Apply fertilizer containing ½ percent boron if pH is above 6.5.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4] Supplemental nitrogen may be needed.
[5]Apply fertilizer containing ¼ percent boron if pH is above 6.5.
[6]Supply zinc in the fertilizer or on the foliage if pH is above 7.2.

Average crop yields expected with management recommeded above, are as follows:

FOR SOUTHERN MICHIGAN

Crops		Groups 2cA-B
Corn	(bu)	110.
Corn silage	(tons)	20.
Field beans	(bu)	35.
Soybeans	(bu)	35.
Sugar beets	(tons)	21.
Wheat	(bu)	60.
Oats	(bu)	95.
Barley	(bu)	65.
Alfalfa	(tons)	4.5
Mixed hay	(tons)	2.7
Pasture	(cow days)	170.

Fertilizer placement recommendations for various crops will be found in the section on Soil Tests and Fertilization.

SOIL MANAGEMENT GROUPS 3a, 3b, 3c, 3/Ra soils

Examples of 3a, 3b, 3c, 3/Ra soils

3a

Dark grayish brown fine granular sandy loam

Yellowish brown very weak platy to granular, loamy sand to sandy loam

Dark brown: subangular blocky sandy clay loam

Brown to yellowish brown: sandy loam glacial till

Hillsdale

3b

Very dark grayish brown granular: sandy loam

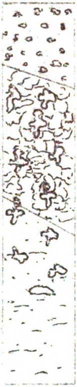
Pale brown mottled with dark yellowish brown weak platy to granular sandy loam

Brown with dark yellowish brown mottles: subangular blocky: sandy clay loam

Pale brown mottled with dark yellowish brown: calcareous sandy loam till

Locke

3c



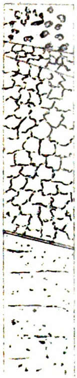
Very dark gr granular loam

Dark grayish brown with distinct mottles subangular blocky sandy clay loam

Light brownis gray with di tinct mottle calcareous sandy loam till

Barry

3/Ra



Very dark grayish brown, fine granular loam

Yellowish brown subangular blocky loam

Dark yellowish brown blocky: sandy clay loam

Olive brown sandstone bedrock

Fill in the name and management unit for all soi in the above management groups that occur on your farm.

Management Unit	Soil Name

GROUPS 3a, 3b, 3c, 3/Ra

Description: These soils were developed in stratified or unstratified sandy loam to silt parent materials or in loamy materials 24 to 42 inches thick over sand and/or gravel or bedrock (R). The 3a group has light colored surfaces and bright colored subsoils. A few, such as the McBride series, have weakly developed fragipans at about 15 to 30 inches in depth. They occur on nearly level to steep areas with deep water tables. Usually acid unless previously limed. The 3b group has moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed but Sanilac series is neutral to limy on the surface. The 3c group has dark colored surfaces and the subsoils are predominantly gray in color. Usually slightly acid to neutral in reaction but the Bach series is limy in the surface. All three groups have moderately high to high readily available moisture holding capacities. All three groups are moderately rapid to moderate in permeability. The 3/Ra group has light colored surfaces and bright colored subsoils. They occur on nearly level to gently rolling areas. Bedrock of limestone or sandstone is within 18 to 42 inches of the surface.

Management problems: Groups 3a, 3/Ra -- (1) control of water erosion, rills form rapidly, (2) need fertilization, (3) usually acid; need lime for legume sods, (4) maintaining organic matter content and preventing crusting after rains, (5) some seep spots may be associated with the fragipan areas or shallow bedrock.

Group 3b -- (1) need fertilization, (2) inadequate drainage, (3) acid unless limed, except for Sanilac series, (4) maintaining organic matter content.

Group 3c -- (1) inadequate drainage, (2) need fertilization.

Crop adaptations: All common farm crops are well adapted where topography and drainage are satisfactory. Among the most productive soils for potatoes. Adapted tree species red pine, white pine, Austrian pine, Ponderosa pine, white spruce, Norway spruce, Scotch pine, and native hardwoods.

Drainage recommendations: Occasionally tile will be needed just above seep spots on slopes in the 3a group. Tile should be placed 3 to 4 feet deep or just above an impermeable layer if one is present. The soils in groups 3b and 3c commonly require drainage for optimum crop yields. Tile lines should be placed 5 to 7 rods apart and 3 to 4 feet deep. If tile are laid in sandy or coarse silty materials, special blinding should be used to prevent these materials from filling the tile. Because ditch banks in stratified materials are unstable when wet, tile lines should be installed when the soils are not wet.

Minimum tillage: All soils in groups "3" are particularly well suited to minimum tillage. Lesser amounts of clay tend to widen the ranges in soil moisture contents that are satisfactory for plowing. The furrows break up readily when they are turned so the field surface is usually quite smooth after plowing. A good job of planting is usually possible without the help of a smoothing device attached to the plow.

Erosion is often severe on 3a soils. Plowing and planting in the same operation, and on the contour, is splendid insurance against loss of water and soil by run-off.

FERTILIZER RECOMMENDATIONS (for soil management groups 3a, 3b and 3c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS: / APPLY:	P-low K-low $N+P_2O_5+K_2O$	P-low K-high $N+P_2O_5+K_2O$	P-high K-low $N+P_2O_5+K_2O$	P-high K-high $N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa,[3] alfalfa-brome,[3] clover, and sweetclover	0+30+80	0+30+40	0+40+80	0+40+40
Alfalfa, after each harvest year[3]	0+45+90	0+45+45	0+30+90	0+22+45
Grass, without a legume	50+25+25	50+25+0	50+0+25	50+0+0
Barley[2] or oats[2] with legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Barley[2,4] or oats [2,4] without legume seeding	25+50+50	25+50+25	12+25+50	25+25+25
Field beans[2,4,5]	15+60+60	15+60+30	15+30+60	15+30+30
Soybeans[2,4]	10+40+40	10+40+20	10+20+40	10+20+20
Wheat[2] or rye with legume seeding	20+80+80	20+80+40	20+40+80	20+40+40
Wheat [2,4] or rye[4] without legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Sugar beets[2,3,4]	30+120+120	30+120+60	30+60+120	30+60+60
Corn[4,5]	15+60+60	15+60+30	15+30+60	15+30+30
Potatoes[2,4]	50+200+200	50+200+100	50+100+200	50+100+100

[2]Where the soil pH is above 6.9, apply fertilizer containing 1 or 2 percent manganese.
[3]Apply fertilizer containing ¼ percent boron for sugar beets and ½ percent for alfalfa if pH is above 6.5.
[4]Supplemental nitrogen may be needed.
[5]Zinc may be needed for 3c soils if pH is above 7.2.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grain will be about 10% less on severely eroded areas that can be cultivated.

FOR SOUTHERN MICHIGAN

Crop		Soil management groups 3a	3b	3c	3/Ra	Crop		Soil management grou[ps] 3a	3b	3c	3/R[a]
Corn grain	(bu)	80	90	95	75	Oats	(bu)	70	75	80	60
Corn silage	(tons)	15	17	18	14	Barley	(bu)	50	55	58	45
Field beans	(bu)	26	28	30	22	Alfalfa	(tons)	3.5	3.7	4.0	3.[illegible]
Soybeans	(bu)	26	30	32	25	Mixed hay	(tons)	2.2	2.6	2.4	2.[illegible]
Sugar beets	(tons)	14	17	18	12	Pasture	(cow days)	145	150	155	11[illegible]
Potatoes	(cwt)	360	325		315	Aspen	(cords)	1.3	0.8	--	--
Wheat	(bu)	40	48	50	35	Red pine	(bd. ft.)	325	250	--	-

Other production and conservation practices: See bottom of next page.

Fertilizer placement recommendations for various crops will be found in the section on Soil Tests and Fertilization.
Lime recommendations will be found in the section on Liming Michigan Soils.

Erosion Control

Maximum C values* of cropping systems recommended for soils of the 3, 3/1 and 3/2 management groups with specified slope classes, erosion classes and erosion control practices. Cropping systems with C values equal to or smaller than these should adequate protect these soils. Compare with the cropping systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.26	0.52	0.24	0.65
B	0,1,2	0.16	0.31	0.24	0.52
	3	0.10	0.21	0.24	0.34
C	1,2	0.63	0.105	0.21	0.14
	3	0.042	0.070	0.14	0.10
D	1,2	0.026	0.032	0.064	Not recom-
	3	0.017	0.021	0.042	mended
E+	1,2,3	Permanent vegetation, grass or trees			

*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

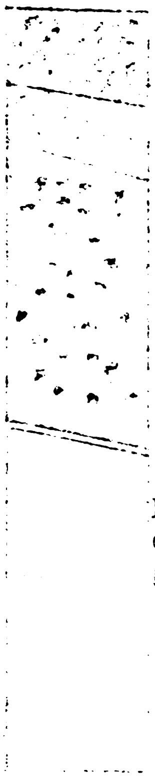
**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for RROM cropping system and 0.11 for the ROMM cropping system.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, and 5) proper timing of all cultural operations.

SOIL MANAGEMENT GROUPS 3/2a, 3/2b, 3/2c, 3/1b, 3/1c soils

Examples of 3/2a, 3/2b, 3/2c soils

3/2a



Grayish brown fine granular loam

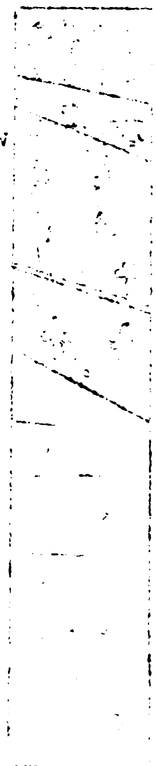
Light brownish yellow granular, sandy loam

Yellowish brown: blocky: gravelly clay loam

Brown: loam: calcareous loam glacial till

Kendallville

3/2b



Dark grayish brown granular: sandy loam

Light brownish gray faintly mottled, platy, sandy loam

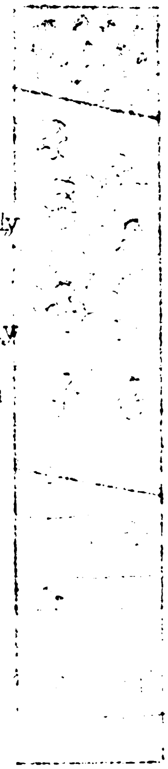
Grayish brown: distinctly mottled blocky sandy loam

Grayish brown distinctly mottled: subangular blocky: sandy clay loam

Brown, mottled: calcareous loam glacial till

Metamora

3/2c



Very dark grayish brown Granular: loam

Grayish brown with distinct mottles: subangular blocky gravelly clay loam

Grayish brown with distinct mottles: calcareous loam till

Berville

Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

GROUPS 3/1b, 3/1c, 3/2a, 3/2b, 3/2c

Description: These soils are developed in stratified sandy loam materials 14 to 42 inches thick over clay to silty clay (3/1) or 18 to 42 inches of stratified sandy loam on clay loams or loam (3/2) materials. The 3/2a soils have light colored surfaces and bright colored subsoils. They have clay to loam substrata. These soils occur on nearly level to steep areas with deep water tables. Usually acid unless previously limed. The 3/1b and 3/2b groups have moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless limed except for the McGregor series which is limy. The 3/1c and 3/2c groups have dark colored surfaces and the subsoils are predominantly grey in color. Usually only slightly acid to neutral in reaction; seldom need lime. All three groups have moderately high readily available water holding capacities. The upper part is rapidly to moderately rapidly permeable and the lower part is slowly (3/2) to very slowly (3/1) permeable.

Management problems: Group 3/2a -- (1) control of erosion, (2) needs fertilization, (3) usually acid and needs lime for legume sods, (4) maintaining organic matter and good tilth.
Group 3/1b and 3/2b -- (1) needs fertilization, (2) inadequate drainage, (3) usually acid, except for McGregor series which has limy surface, (4) Maintaining organic matter content.
Group 3/1c and 3/2c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptations: All common farm crops are well adapted where topography and drainage are adequate. Among the most productive soils for potatoes. Seldom planted to trees except on eroded or steep areas. Adapted species for that purpose are white, red, Austrian, Ponderosa and Scotch pine or Norway spruce. Red pine is not adapted to areas where the limy or neutral subsoil is exposed.

Drainage recommendations: Occasionally, tile will be needed just above seep spots on slopes in the 3/2a group. Tile should be placed 3 to 4 feet deep or just above the finer substratum, but not less than 30 inches deep. On the 3/1b and 3/1c groups the tile lines should be 2 to 4 rods apart and on the 3/2b and 3/2c groups the tile lines should be 4 to 6 rods apart and 3 to 4 feet deep. Some wet spots can be drained by tile spurs. Surface drainage should be used whenever necessary to prevent ponding of water. Because of the variable depth of the finer substratum, on site investigations should be made before designing the tile system in each field. Some wet spots may lack adequate outlets. These areas may be fertilized and seeded for permanent pasture. Reed canary grass is well adapted to such areas. Alternatively, catch basins and sump pumps may be used to provide adequate outlets.

Minimum tillage: All soils in groups "3" are particularly well suited to minimum tillage. Lesser amounts of clay tend to widen the ranges in soil moisture contents that are satisfactory for plowing. The furrows break up readily when they are turned so the field surface is usually quite smooth after plowing. A good job of planting is usually possible without the help of a smoothing device attached to the plow.

Erosion is often severe on 3a soils. Plowing and planting in the same operation, and on the contour, is spendid insurance against loss of water and soil by run-off. In soils with a shallow upper story drainage is slower and one should be more careful to avoid plowing when subsoils are too wet.

FERTILIZER RECOMMENDATIONS (for soil management groups 3/1b, 3/1c, 3/2a, 3/2b, 3/2c lbs per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS: ▷	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY: ▷	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa,[3] alfalfa-brome,[3] clover, and sweet clover	0+80+80	0+80+40	0+40+80	0+40+40
Alfalfa, after each harvest year[3]	0+45+90	0+45+45	0+30+90	0+22+45
Grass, without a legume	50+25+25	50+25+0	50+0+25	50+0+0
Barley[2] or oats[2] with legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Barley[2,4] or oats[2,4] without legume seeding	25+50+50	25+50+25	12+25+50	25+25+25
Field beans[2,4,5]	15+60+60	15+60+30	15+30+60	15+30+30
Soybeans[2,4]	10+40+40	10+40+20	10+20+40	10+20+20
Wheat[2] or rye with legume seeding	20+80+80	20+80+40	20+40+80	20+40+40
Wheat[2,4] or rye[4] without legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Sugar beets[2,3,4]	30+120+120	30+120+60	30+60+120	30+60+60
Corn[4,5]	15+60+60	15+60+30	15+30+60	15+30+30
Potatoes[2,4]	50+200+200	50+200+100	50+100+200	50+100+2[illegible]

[2]Where the soil pH is above 6.9, apply fertilizer containing 1 or 2 percent manganese.
[3]Apply fertilizer containing ½ percent boron for sugar beets and ½ percent for alfalfa if pH is above 6.5.
[4]Supplemental nitrogen may be needed.
[5]Zinc may be needed for 3/2c soils if pH is above 7.2.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grain crops will be about 20% less on severely eroded areas that can be cultivate.

Crops		Soil management group 3/2a	3/1b or 3/2b	3/1c or 3/2c	Crops		Soil management group 3/2a	3/1b or 3/2b	3/1c or 3/2c
Corn	(bu)	85	95	100	Oats	(bu)	75	82	87
Corn silage	(tons)	16	18	19	Barley	(bu)	53	57	61
Field beans	(bu)	27	30	32	Alfalfa	(tons)	3.7	3.8	4.2
Soybeans	(bu)	27	31	33	Mixed hay	(tons)	2.4	2.7	
Sugar beets	(tons)	15	17	19	Pasture	(cow days)	147	153	160
Potatoes	(cwt)	330	300	--	Aspen	(cord)	1.3	0.8	--
Wheat	(bu)	43	50	55	White pine	(bd. ft)	300	--	--

Fertilizer placement recommendations for various crops will be found in section on Soil Tests and Fertilization.

Lime recommendations are given in section on Liming Michigan Soils.

Erosion Control

Maximum C values* of cropping systems recommended for soils of the 3, 3/1 and 3/2 management groups with specified slope classes, erosion classes and erosion control practices. Cropping systems with C values equal to or smaller than these should adequate protect these soils. Compare with the cropping systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.26	0.52	0.24	0.65
B	0,1,2	0.16	0.31	0.24	0.52
	3	0.10	0.21	0.24	0.34
C	1,2	0.63	0.105	0.21	0.14
	3	0.042	0.070	0.14	0.10
D	1,2	0.026	0.032	0.064	Not recom- mended
	3	0.017	0.021	0.042	
E+	1,2,3	Permanent vegetation, grass or trees			

*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

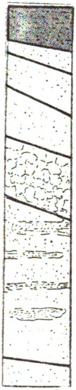
**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for RROM cropping system and 0.11 for the ROMM cropping system.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, and 5) proper timing of all cultural operations.

SOIL MANAGEMENT GROUPS 4a, 4b, 4c, 4/Ra, 4/Rb soils

Examples of 4a, 4b, 4c, 4/Ra, 4/Rb soils

4a



Dark grayish brown loamy sand
Light gray loamy sand
Yellowish brown loamy sand
Light yellowish brown loamy sand
Brown: subangular blocky: sandy loam to sandy clay loam
Pale brown sand with bands of brown sandy loam
Yellowish brown calcareous loamy sand

Montcalm

4b

Very dark grayish brown loamy sand
Light brownish gray loamy sand
Yellowish brown with distinct mottles: loamy sand
Pale brown, distinctly mottled: loamy sand
Dark yellowish brown subangular blocky sandy loam to sandy clay loam
Brownish yellow: calcareous loamy sand

Otisco

4c

Black sandy loam
Grayish brown mottled: loamy sand
Mottled gray loamy sand

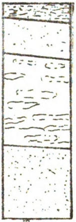
Edmore

4/Ra

Black loamy sand
Pinkish gray sand
Dark brown loamy sand
Limestone bedrock

Duel

4/Rb



very dark gray loamy sand
Light brownish gray loamy sand
Light gray loamy sand with many sandstone fragments
Sandstone bedrock

Tyre

Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit ________________ Soil Name ________________

____

____

____

____

GROUPS 4a, 4b, 4c, 4/Ra, 4/Rb

Description: These soils are developed in stratified or unstratified loamy sand materials, sandy loam materials on stratified sands and gravel within 42 inches, or in sands or loamy sands with thin finer textured bands within 36 inches of the surface. The 4a group has light colored surfaces and bright colored subsoils. It occurs on nearly level to steep areas with low water tables. Usually acid unless previously limed. The 4b group has moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed. The 4c group of soils has dark colored surfaces and the subsoils are predominantly grey in color. Usually slightly acid to neutral in reaction. All three groups have moderately high to high readily available moisture holding capacities. All three groups have moderately rapid to rapid permeabilities. The 4/Ra and 4/Rb soil groups are underlain by limestone or sandstone bedrock within 18 to 42 inches of the surface. They are more droughty than the 4a and 4b groups.

Management problems: Groups 4a, 4/Ra -- (1) control of erosion, rills form readily, (2) need fertilization, (3) usually acid, need lime for legume sods, (4) maintaining organic matter content.
Group 4b, 4/Rb -- (1) need fertilization, (2) inadequate drainage, (3) acid unless limed, (4) maintaining organic matter content.
Group 4c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptations: Where topography and drainage are satisfactory, all common farm crops are fairly well adapted except sugar beets and field beans. Adapted tree species for planting on the well drained group are red pine, white pine, Scotch pine and jack pine. White pine, Austrian pine or Norway spruce are adapted to some of the imperfectly drained areas.

Drainage recommendations: The 4b and 4c groups need improved drainage for most crops. They can be adequately drained with open ditches or by tile lines 6 to 8 rods apart. To prevent the tile lines from filling with sand they should be blinded with topsoil, straw or similar materials. It may be necessary to delay ditching and tiling until the dry season of the year.

Minimum tillage: These soils are especially well adapted to minimum tillage. They can be plowed at a wide range of soil moisture and the furrows usually roll over to leave a loose smooth surface. Excessive furrowing by the planting mechanism and/or by the wheels of the tractor pulling the planter may be avoided by pulling a packer behind the plow. Plowing and planting in the same operation is advised for these soils.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, and 5) proper timing of all cultural operations.

FERTILIZER RECOMMENDATIONS (for soil management groups 4a, 4b and 4c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS: ⇨	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY: ⇨	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELD GIVEN IN THE TABLE BELOW				
Alfalfa,[2] alfalfa-brome,[2] clover and sweetclover	0+60+60	0+60+30	0+30+60	0+30+30
Alfalfa after each harvest year[2]	0+30+90	0+30+45	0+30+90	0+15+45
Grass without legume	50+25+25	50+25+0	50+0+25	50+0+0
Barley[3,4] or oats[3,4] with legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Barley[3,4] or oats[3,4] without legume seeding	16+32+32	16+32+16	8+16+32	16+16+16
Field beans[3,4] and	10+40+40	10+40+20	10+20+40	10+20+20
soybeans[3,4]	7.5+30+30	7.5+30+15	7.5+15+30	7.5+15+15
Wheat[3,4] or rye[3,5] with legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Wheat[3,4] or rye[3] without legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Corn[3]	10+40+40	10+40+20	10+20+40	10+20+20
Potatoes[3,4]	50+150+200	50+150+100	50+75+200	50+75+100

[2]Apply fertilizer containing ½ percent boron if pH is above 6.5.
[3]Supplemental nitrogen may be needed.
[4]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.

Average crop yields expected with practices recommended above. Yields of crops on the 4/Ra and 4/Rb groups are 30-40 percent less than cited below

Crops	Soil management group 4a	4b	4c
Corn grain (bu)	70	80	85
Corn silage (tons)	13	15	16
Field beans (bu)	19	24	28
Soybeans (bu)	23	27	31
Potatoes (cwt)	275	250	--
Wheat (bu)	30	38	45
Oats (bu)	53	63	70
Barley (bu)	40	45	50
Alfalfa (tons)	3.2	3.5	3.7
Mixed hay (tons)	1.8	2.1	2.2
Pasture (cow days)	90	120	135
Aspen (cords)	0.3	0.6	-
Red pine (bd. ft.)	300.	250.	-

Fertilizer placement recommendations for various crops will be found in the section on Soil Tests and Fertilization.
Lime recommendations will be found in the section on Liming Michigan Soils.

Erosion Control

Maximum C values* of cropping systems that will control erosion on soils of 4, 4/1 and 4/2 management groups*** with specified slope classes, erosion classes, and conservation practices as indicated. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the C values for cropping and management systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.35	0.51	0.24	0.52
	3	0.23	0.46	0.24	0.52
B	0,1,2	0.21	0.41	0.24	0.52
	3	0.14	0.28	0.24	0.45
C	1,2	0.084	0.14	0.24	0.21
	3	0.056	0.93	0.19	0.14
D	1,2	0.034	0.042	0.084	Not recom-
	3	0.023	0.028	0.056	mended
E+		Permanent vegetation, grass or trees			

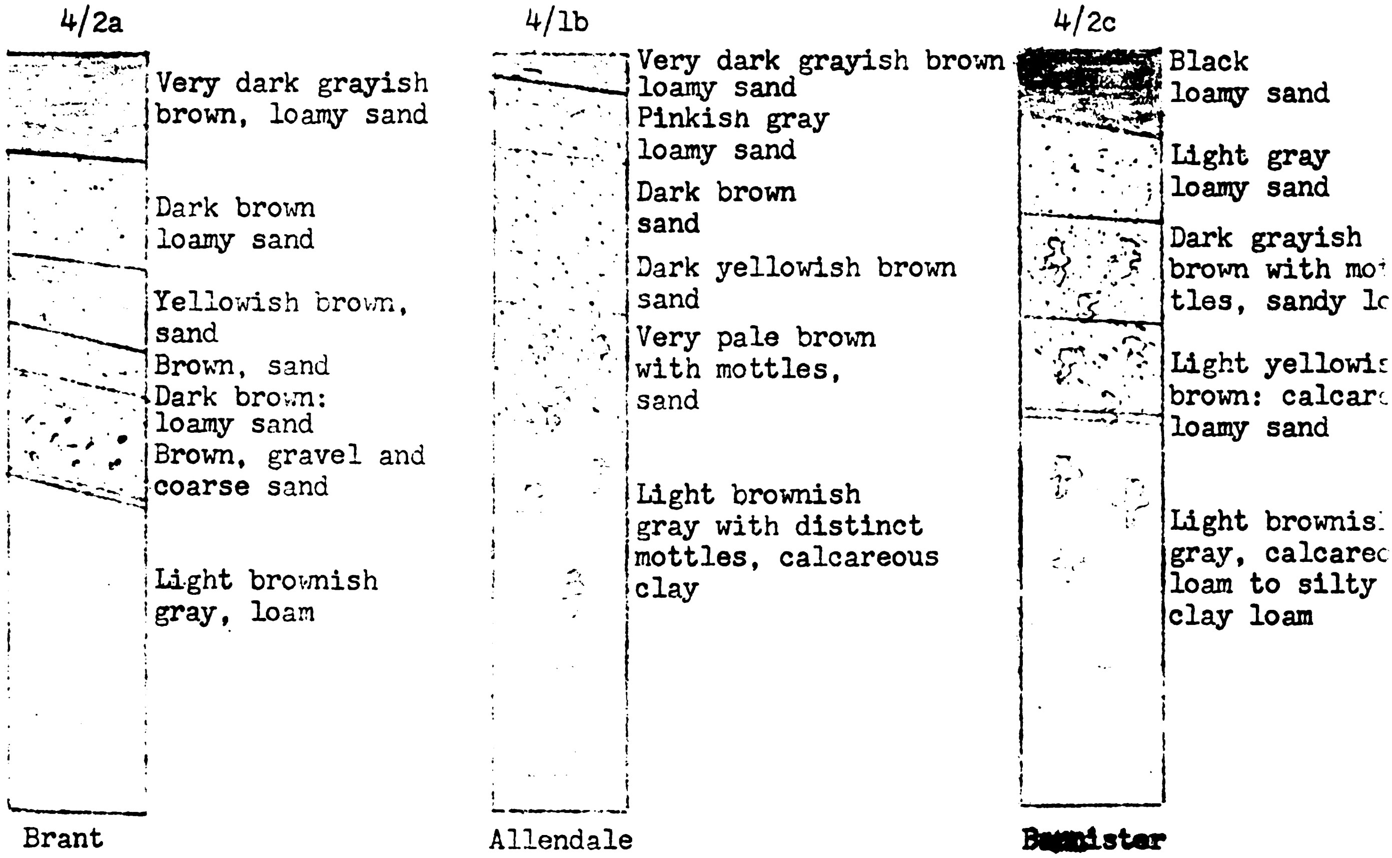
*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for RROM cropping system and 0.11 for the ROMM cropping system.

***Thin solum members of the 4 groups (e.g. Pence, Kiva and Casco) should use cropping systems with only 0.5 of these C values.

SOIL MANAGEMENT GROUPS 4/1b, 4/1c, 4/2a, 4/2b, 4/2c soils

Examples of 4/2a, 4/1b, 4/2c soils



Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

GROUPS 4/1b, 4/1c, 4/2a, 4/2b, 4/2c

Description: All of these soils are developed in sands to loamy sands 14 to 42 inches thick over clay or silty clay (4/1) or sands to loamy sands 18 to 42 inches thick over clay loams or loam (4/2). The 4/2a soils have light colored surfaces and bright colored subsoils. They occur on nearly level to steeply sloping areas with deep water tables and may be underlain by clays, silty clays, clay loams or loam. Usually acid unless previously limed. The 4/1b and 4/2b soils have moderately dark colored surfaces and mottled subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Usually acid unless previously limed. The 4/1c and 4/2c soils have dark colored surfaces and the subsoils are predominantly grey in color. They are commonly only slightly acid to neutral but the Essexville series has free lime in the surface. All these soils have moderate to moderately high available water holding capacities. Their upper parts are rapidly to very rapidly permeable and the lower parts are slowly permeable in the 4/2 and very slowly permeable in the 4/1 groups.

Management problems: Group 4/2a -- (1) water and wind erosion control, (2) needs fertilization, (3) usually acid and need lime for legume sods, (4) maintaining organic matter content.

Groups 4/1b and 4/2b -- (1) need fertilization, (2) inadequate drainage, (3) usually acid and need lime for legume sods.

Groups 4/1c and 4/2c -- (1) inadequate drainage, (2) need fertilization.

Crop adaptations: Where topography and drainage are adequate, all common farm crops are well adapted, except sugar beets and field beans. Adapted tree species for planting the better drained areas are red, white, Austrian, or Scotch pines. These species and Norway spruce are also adapted to some of the imperfectly drained areas.

Drainage recommendations: Occasionally, tile will be needed just above seep spots on slopes in the 4/2a group. The tile should be placed 3 to 4 feet deep or just above the finer substratum but not less than 30 inches deep. On the 4/1b or 4/1c groups tile lines should be 2 to 4 rods apart and on the 4/2b or 4/2c groups the tile lines should be 4 to 6 rods apart. On all these groups they should be 3 to 4 feet deep. Some wet spots can be drained by tile spurs. Tile should be blinded with topsoil or straw to prevent sand filling them. It may be necessary to lay the tile when the soil is not wet Surface drainage should be used wherever necessary to prevent ponding.

Minimum tillage: These soils are especially well adapted to minimum tillage. They can be plowed at a wide range of soil moisture and the furrows usually roll over to leave a loose smooth surface. Excessive furrowing by the planting mechanism and/or by the wheels of the tractor pulling the planter may be avoided by pulling a packer behind the plow. Plowing and planting in the same operation is advised for these soils.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) application of fertilizers according to test as described on the next page, 4) control of weeds by cultivation or sparys, 5) return of crop residues to the soil, and 6) proper timing of all cultural operations.

FERTILIZER RECOMMENDATIONS (for soil management groups 4/1b, 4/1c, 4/2a, 4/2b, 4/2c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS:	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa[2], alfalfa-brome[2], clover and sweetclover	0+60+60	0+60+60	0+30+60	0+30+30
Alfalfa after each harvest year[2]	0+30+90	0+30+45	0+30+90	0+15+45
Grass without legume	50+25+25	50+25+0	50+ 0+25	50+ 0+ 0
Barley[3,4] or oats[3,4] with legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Barley[3,4] or oats[3,4] without legume seeding	16+32+32	16+32+16	8+16+32	16+16+16
Field beans[3,4]	10+40+40	10+40+20	10+20+40	10+20+20
soybeans[3,4]	7.5+30+30	7.5+30+15	7.5+30+15	7.5+15+15
Wheat[3,4] or rye[3,5] with legume seeding	15+60+60	15+60+30	15+30+60	15+30+30
Wheat[3,4] or rye[3] without legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Corn[3]	10+40+40	10+40+20	10+20+40	10+20+20
Potatoes[3,4]	50+150+200	50+150+100	50+75+200	50+75+100

[2]Apply fertilizer containing 1/2 percent boron if pH is above 6.5.
[3]Supplemental nitrogen may be needed.
[4]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese to 4/ c soils.

Average crop yields expected with practices recommended above on uneroded to moderately eroded soils. Yields of non-legume row crops or small grain will be about 10% less on severely eroded areas that can be cultivated.

Crop		Soil mgt. groups 4/2a	4/2b, 4/1b	4/2c, 4/1c	Crop		Soil mgt. groups 4/2a	4/2b, 4/1b	4/2c, 4/1c
Corn grain	(bu.)	75	85	90	Oats	(bu.)	60	70	75
Corn silage	(tons)	14	16	17	Barley	(bu.)	45	50	54
Field beans	(bu.)	22	26	29	Alfalfa	(tons)	3.3	3.6	3.8
Soybeans	(bu.)	25	29	31	Mixed hay	(tons)	2.2	2.4	2.6
Sugar beets	(tons)	12	14	16	Pasture	(cow days)	115	135	160
Potatoes	(cwt.)	275	250		Aspen	(cords)	1.3	0.8	-
Wheat	(bu.)	35	43	47	Red pine	(bd. ft.)	325	250	-

Lime recommendations are given in the section on Liming Michigan Soils.

Erosion Control

Maximum C values* of cropping systems that will control erosion on soils of 4, 4/1 and 4/2 management groups*** with specified slope classes, erosion classes, and conservation practices as indicated. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the C values for cropping and management systems in Table 4A.

		Erosion control practices			
Slope class	Erosion classes	Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2	0.35	0.51	0.24	0.52
	3	0.23	0.46	0.24	0.52
B	0,1,2	0.21	0.41	0.24	0.52
	3	0.14	0.28	0.24	0.45
C	1,2	0.084	0.14	0.24	0.21
	3	0.056	0.93	0.19	0.14
D	1,2	0.034	0.042	0.084	Not recom-
	3	0.023	0.028	0.056	mended
E+		Permanent vegetation, grass or trees			

*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for RROM cropping system and 0.11 for the ROMM cropping system.

***Thin solum members of the 4 groups (e.g. Pence, Kiva and Casco) should use cropping systems with only 0.5 of these C values.

SOIL MANAGEMENT GROUPS: 5a, 5b, 5c, 5a-h, 5b-h, 5.3a and 5.7a soils

Examples of 5a-h, 5.3a, 5.7a, 5b-h and 5c soils

5a-h

Wallace

5.3a

Rubicon

5.7a

Grayling

5b-h

augatuck

5c

Roscommon

Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

Groups 5a, 5b, 5b-h, 5c, 5.3a, 5a-h, 5.7a

Description: These soils were formed in sands over 66 inches deep but some of the 5c group may have finer textured materials at between 42 and 66 inches beneath the surface. The 5a, 5a-h, 5.3a and 5.7a groups all have light colored surfaces and bright colored subsoils. The upper part of the subsoil is the darkest in the 5a or 5a-h and lightest in the 5.7a group. The 5a-h group has a cemented subsoil layer. They all occur on nearly level to steeply sloping areas with deep water tables. The 5b and 5b-h groups have moderately dark colored surfaces and mottled subsoils. These soils occur on nearly level to gently sloping areas with seasonally high water tables. The 5b-h group has a cemented subsoil. The 5c group has dark colored surfaces and the subsoils are predominantly grey in color. The 'a' groups have low to very low readily available moisture holding capacities and this decreases from the 5a to the 5.3a to the 5.7a and 5a-h groups. The 5b and 5c groups have moderate readily available moisture holding capacities. These soils are all very rapidly permeable. The 'a' and 'b' groups are all acid unless previously limed. The 5c group is usually slightly acid to neutral, except the Tobico series which is limy, and the Kinross series which is acid.

Management problems: Group 5a if cultivated -- (1) wind erosion, (2) needs fertilization, (3) maintaining organic matter content, (4) drouthiness, (5) acidity.

Groups 5a-h, 5b-h, 5.3a and 5.7a -- reforestation or pasture improvement.

Group 5b -- (1) needs fertilization, (2) inadequate drainage, (3) acidity, (4) maintaining organic matter content.

Group 5c -- (1) inadequate drainage, (2) needs fertilization.

Crop adaptatations: Yields of common farm crops on group 5a are low unless well managed. Fertilization and irrigation have been used successfully for special crops. These soils are best suited to deep rooted crops, winter grains, and short season crops such as potatoes. These were native hardwood lands but many of these areas have been replanted to red or jack pine, or are used for wildlife pasture. The 5a-h, 5b-h, 5.3a and 5.7a groups are best suited for forestry or wildlife. They were native pine lands. The 5b and 5c areas may be fair pasture lands if fertilized and seeded with ladino clover, alsike clover, Dutch white clover, bromegrass, bluegrass, or other suitable species.

Drainage recommendations: The 5b and 5c groups may be drained with open ditches. If tile are used the lines should be 6 to 8 rods apart and 3 to 4 feet deep. They should be blinded with topsoil, straw or similar material.

Minimum tillage: Group 5 soils are very well adapted to minimum tillage. Plowing of these soils is done essentially to cover vegetationand trash. Wind erosion is a serious problem when they are bare, so planting should immediately follow plowing. In other words, provide for revegetation as soon as possible. Plowing and planting in the same operation is recommended where feasible.

Attach a crow-foot roller or revolving-bladded tiller to the plow if possible. Slightly packing the soil behind the plow may make the planting operation easier and more accurate. This is especially true of small grains.

FERTILIZER RECOMMENDATIONS (for soil management groups 5a, 5b and 5c) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS:	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY:	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa[2], alfalfa-brome[2], clover, and sweetclover	0+45+90	0+45+45	0+30+30	0+22+45
Alfalfa after each harvest year[2]	0+30+90	0+30+30	0+30+90	0+15+45
Grass without a legume	30+30+30	30+30+0	30+0+30	30+0+0
Oats[3,4] without a legume seeding	16+32+32	16+32+16	8+16+32	16+16+16
Wheat[3,4] or rye[4] without legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Corn[4] (unirrigated)	10+40+40	10+40+20	10+20+40	10+20+20
Corn[4] (irrigated)	50+100+120	50+100+100	50+50+100	50+50+100
Potatoes[3,4]	30+60+120	30+60+60	13+40+120	15+30+60
Cover crop (fall) oats rye	10+40+40	10+40+20	10+20+40	10+20+20
Cover crop (summer) Sudangrass, oats, buckwheat	30+30+30	30+30+0	30+15+30	30+15+15

[2]Apply fertilizer containing 1/2 percent boron.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be added.

Average crop yields expected with practices recommended above.

Crops	Soil management group 5.7a	5.3a	5.0a	5.b	5c
Corn (irrigated) (bu.)	-	-	120.	120.	-
Corn grain (bu.)	-	-	46.	56.	70.
Corn silage (tons)	-	-	9.	10.	13.
Potatoes (cwts.)	-	-	180.	200.	-
Wheat (bu.)	-	-	23.	31.	35.
Oats (bu.)	-	-	40.	47.	55.
Alfalfa (tons)	-	-	1.8	2.8	3.2
Mixed hay (tons)	-	-	1.2	1.3	1.5
Pasture (cow days)	-	35.	65.	90.	115.
Aspen (cords)	-	0.3	0.8	0.3	-
Red pine (bd. ft.)	130.	240.	270.	240.	-

Erosion Control

Maximum C values* of cropping systems that will control erosion on soils of 5, and 5/2 management groups with specified slope classes, erosion classes and conservation practices as indicated. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the C values for cropping and management systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2,3	0.51	0.51	0.24	Not used
B	0,1,2,3	0.48	0.51	0.24	0.51
C	1,2,3	0.20	0.34	0.24	0.50
D	1,2,3	0.079	0.099	0.20	Not recom-
E	1,2,3	0.040	0.050	0.10	mended
F+		Continuous vegetative cover, grass or trees			

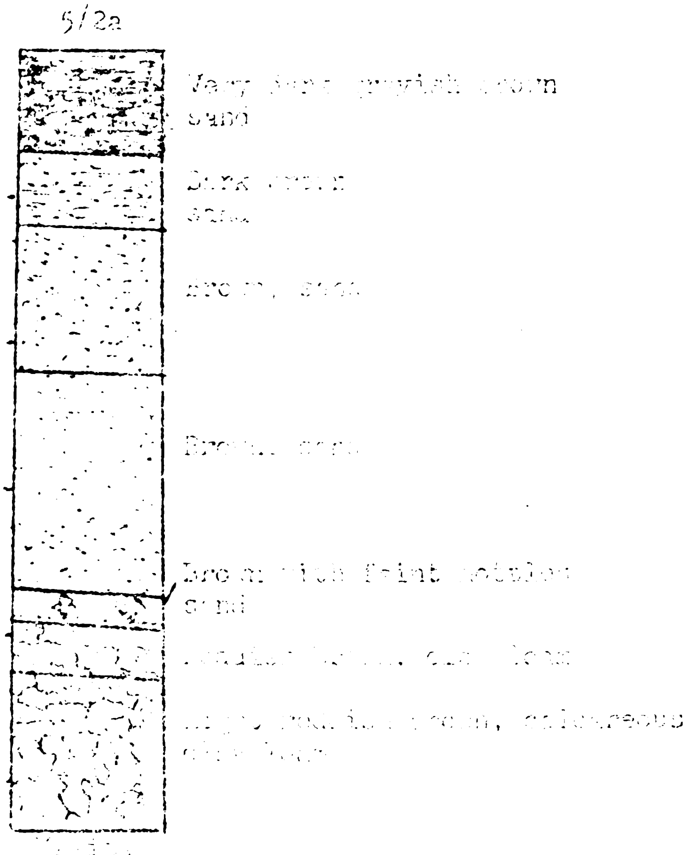
*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

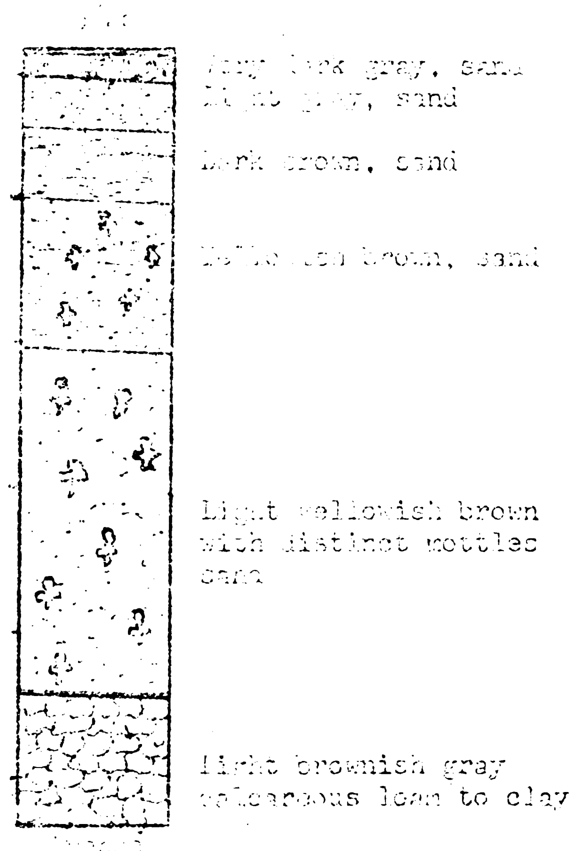
**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for the RROM cropping system and 0.11 for the ROMM cropping system.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, 5) proper timing of all cultural operations, and 6) windbreaks and/or strip cropping to prevent wind erosion on these sandy soils.

SOIL MANAGEMENT GROUPS: 5/2a and 5/2b soils

Examples of 5/2 and 5/2b soils.





Fill in the name and management unit for all soils in the above management groups that occur on your farm.

Management Unit	Soil Name

GRCUPS 5/2a, 5/2b

Description: These soils were formed in 42 to 66 inches of sand over loam to clay materials. The 5/2a group has light colored surfaces and bright colored subsoils. These soils occur on nearly level to steeply sloping areas with deep water tables. The 5/2b group has maderately dark colored surfaces and mottles subsoils. They occur on nearly level to gently sloping areas with seasonally high water tables. Both groups have moderate readily available water holding capacities. They are commonly acid unless limed. The upper part is very rapidly permeable but the lower part is slowly to very slowly permeable.

Management problems: Group 5/2a -- (1) wind and water erosion control (2) need fertilization, (3) usually acid and need lime for legume sods, (4) drouthiness.

Group 5/2b -- (1) need fertilization, (2) inadequate drainage, (3) wind erosion control, (4) acidity.

Crop adaptations: Deep rooted crops, winter grains, and short season crops are best adapted. Pastures produce well if fertilized and reseeded. Tree species suitable for planting include red pine, jack pine and white pine.

Drainage recommendations: The 5/2b group can be adequately drained by open ditches or by tile lines 6 to 8 rods apart. To prevent the tile lines from filling with sand, they should be blinded with topsoil, straw or similar materials. It may be necessary to delay ditching and tiling until the dry season of the year.

Minimum tillage: Group 5 soils are very well adapted to minimum tillage. Plowing of these soils is done essentially to cover vegetation and trash. Wind erosion is a serious problem when they are bare, so planting should immediately follow plowing. In other words, provide for revegetation as soon as possible. Plowing and planting in the same operation is recommended where feasible.

Attach a crow-foot roller or revolving-bladded tiller to the plow if possible. Slightly packing the soil behind the plow may make the planting operation easier and more accurate. This is especially true of small grains.

FERTILIZER RECOMMENDATIONS (for soil management groups 5/2a, and 5/2b) in pounds per acre of nitrogen, N; phosphate, P_2O_5; and potash, K_2O. For supplemental fertilizer recommendations, see tables 6, 7 and 8 in the section on Soil Tests and Fertilization.

IF SOIL TEST SHOWS: →	P-low K-low	P-low K-high	P-high K-low	P-high K-high
APPLY: →	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$	$N+P_2O_5+K_2O$
ON THESE CROPS WITH THE YIELDS GIVEN IN THE TABLE BELOW				
Alfalfa[2], alfalfa-brome[2], clover, and sweetclover	0+45+90	0+45+45	0+30+30	0+22+45
Alfalfa after each harvest year[2]	0+30+90	0+30+30	0+30+90	0+15+45
Grass without a legume	30+30+30	30+30+0	30+0+30	30+0+0
Oats[3,4] without a legume seeding	16+32+32	16+32+16	8+16+32	16+16+16
Wheat[3,4] or rye[4] without legume seeding	12+50+50	12+50+25	12+25+50	12+25+25
Corn[4] (unirrigated)	10+40+40	10+40+20	10+20+40	10+20+20
Corn[5] (irrigated)	50+100+120	50+100+100	50+50+100	50+50+100
Potatoes[3,4]	30+60+120	30+60+60	13+40+120	15+30+60
Cover crop (fall) oats rye	10+40+40	10+40+20	10+20+40	10+20+20
Cover crop (summer) Sudangrass, oats, buckwheat	30+30+30	30+30+0	30+15+30	30+15+15

[2]Apply fertilizer containing 1/2 percent boron.
[3]Where pH is above 6.5, apply fertilizer containing 1 or 2 percent manganese.
[4]Supplemental nitrogen may be added.

Average crop yields expected with practices recommended above.

Crops		Soil management groups 5/2a	5/2b
Corn, grain	(bu.)	53.	56.
Corn, silage	(tons)	11.	11.
Wheat	(bu.)	24.	26.
Oats	(bu.)	53.	56.
Alfalfa	(tons)	2.8	2.6
Mixed hay	(tons)	1.7	1.9
Pasture	(cow days)	70.	88.
Aspen	(cords)	0.8	0.5
Red pine	(bd. ft.)	285.	245.

Erosion Control

Maximum C values* of cropping systems that will control erosion on soils of 5, and 5/2 management groups with specified slope classes, erosion classes and conservation practices as indicated. Cropping systems with C values equal to or smaller than these should adequately protect these soils. Compare with the C values for cropping and management systems in Table 4A.

Slope class	Erosion classes	Erosion control practices: Up & down slopes	Contour	Contour strips**	Terraces
A	0,1,2,3	0.51	0.51	0.24	Not used
B	0,1,2,3	0.48	0.51	0.24	0.51
C	1,2,3	0.20	0.34	0.24	0.50
D	1,2,3	0.079	0.099	0.20	Not recom-
E	1,2,3	0.040	0.050	0.10	mended
F+		Continuous vegetative cover, grass or trees			

*These values are based on slopes 200 feet long, the median % slope of each slope class, and a rainfall intensity factor of R = 100.

**Strip cropping involves alternate strips of row crops with small grain and/or sod crops. As examples, the maximum C values for this system are 0.24 for the RROM cropping system and 0.11 for the ROMM cropping system.

Other production and conservation practices important in the success of a cropping system are: 1) use of certified seed of adapted varieties, 2) seed treatment with fungicides and insecticides, 3) control of weeds by cultivation or sprays, 4) return of crop residues to the soil, 5) proper timing of all cultural operations, and 6) windbreaks and/or strip cropping to prevent wind erosion on these sandy soils.

GROUPS Ga, Gc

Description and management suggestions: These are very cobbly, stony or gravelly areas that should ordinarily remain in permanent vegetation. The Ga areas are well to moderately well drained but the Gc areas are imperfectly to poorly drained. These soils are too stony, cobbly or gravelly to be artificially drained. Areas in pasture should be seeded to adapted species and fertilized wherever possible according to the recommendation for Group 4 soils. Many of these soils contain limestone fragments and do not need lime. Where tree plantings are planned, suitable species are white cedar, white spruce, and white pine.

GROUPS L2a, L2c, L4a, L4c

Description: These are lowland areas along streams that are subject to overflow seasonally. The L2a and L2c groups are developed on stratified moderately coarse (sandy loams) to moderately fine textured (clay loams) alluvium. The L4a and L4c groups are developed in stratified coarse textured alluvium. The 'a' groups have relatively light colored surfaces and relatively bright colored subsoils. They occur in areas with relatively deep water tables. The 'c' groups have relatively dark colored surfaces and mottled or grey subsoils. They occur in areas with seasonally or permenently high water tables All four groups occur on nearly level areas but winding low ridges and old stream channels frequently are present. These soils are commonly neutral to alkaline in reaction.

Management problems: (1) overflow may damage crops, delay planting and cause depositions of new sediments, or result in erosion along stream banks in these areas; (2) areas are frequently too small, too inaccessable, too cut up by stream channels to be suitable for cultivation; (3) inadequate drainage; and (4) early frost hazards.

Crop adaptations: Many of these soils are used for permanent pastures or woodlots. Grasses such as smooth brome grass and moisture tolerant legumes such as white, ladino and alsike clover are recommended on imperfectly drained areas. Reed canary grass may be used on poorly drained areas. These areas are seldom planted to trees; red maple and cottonwood are adapted species. Where the areas are large enough and protected from overflow by dredging of the stream channel or building of levees, cultivated crops may be grown. Summer crops such as corn are best adapted. Lime is seldom needed — if needed, apply as suggested in Liming section. Fertilize the L2 and L4 groups as recommended for Groups 2 and 4, respectively.

Drainage: Dredging of streams has improved drainage of some areas. Diversion ditches may be needed for interception of water from adjoining uplands. If areas are large enough and protected from overflow, tile can be used as suggested for Group 3 soils.

Expected crop yields are variable because of overflow damage. Where protected from overflow and adequately drained the yield on the L2 group should be similar to those on Group 2 and the yields on the L4 group should be similar to those on Group 4.

GROUPS Mc, Mc-a, M/1c, M/3c, M/4c, M/mc

Description: Organic soils, mucks or peats, 12 inches or more thick. These are nearly level, very poorly drained areas. Except for the extremely acid group (Mc-a) these soils are well supplied with bases and seldom need lime. They are naturally low in potash and phosphorus and often low in manganese, boron copper, molybdenum and zinc. When adequately drained and properly fertilized they are productive soils.

Mc -- Deep organic soils, over 42 inches thick. The Lupton series may contain free lime in the surface (see also M/mc below).

Mc-a -- Extremely acid organic soils over 12 inches thick. Low in bases. When lime is applied, dolomitic lime is recommended. Amounts shown in Lime Sec. should be mixed with the soil to a depth of 12 to 15 inches. Some areas composed largely of a mixture of sedge and sphagnum peat are used for commercial peat. Where undrained, these areas are used only by wildlife or may produce some wild blueberries. A few areas have been limed, fertilized and used for vegetable production. Nitrogen, copper and molybdenum are commonly low. Manganese may be low after liming.

M/1c -- Shallow organic soils on clays within 12 to 42 inches. Drainage is more difficult than in other organic soils.

M/3c -- Shallow organic soils on loams within 12 to 42 inches.

M4/c -- Shallow organic soils on sands within 12 to 42 inches. These are less durable and less productive than the deeper organic soils or those on finer textured materials.

M/mc -- Shallow organic soils on marl. Tile drainage is difficult. These soils and the Lupton series in group Mc are commonly too limy for onions, spinach, soybeans, lettuce, or wheat. Application of sulfur to lower the pH is not practical where free lime is abundant.

Management problems: Water control (drainage, water table regulation, and irrigation); proper fertilization (including micronutrients); frostiness; wind erosion control; and fire prevention. Some other management problems peculiar to the individual groups are mentioned above.

Crop adaptations: If adequately drained these soils are suitable for many short season, frost resistant or hardy perennial plants or for pasture. Grasses, celery, carrots, or cabbages are frost resistant and spinach, sugar beets, head lettuce, small grains and onions are moderately resistant. Other crops sometimes grown on these soils in Southern Michigan are shown in the table at the end of this section. Intertilled crops can be grown continuously with proper fertilization. Where cleared but undrained, reed canary grass does well. Brome grass, orchard grass, timothy, alsike clover, and ladino clovers are adapted for the better drained areas. Trees are not planted except as windbreaks on drained areas. Native trees grow slowly.

FERTILIZER RECOMMENDATIONS FOR ORGANIC SOILS: Where not previously fertilized only pH tests are recommended. If previously fertilized, samples should be taken and tested before fertilizer is to be applied.

Phosphate fertilizer recommendations for organic soils based upon crop and available soil phosphorus using Bray P_1 method

Available soil phosphorus pounds per acre of "P"				Pounds P_2O_5 per acre recommended
			15	200
		10	30	160
		20	40	130
	10	40	60	100
5	20	60	80	75
15	40	30	110	50
30	60	100+	140!	30
50+	75+	---	---	20
blueberries buckwheat clover grass oats rye soybeans pasture	alfalfa asparagus barley beans corn mint peas radishes sudan grass sweet corn turnips wheat	cabbage carrots cucumbers endive lettuce parsnips potatoes pumpkins spinach sugar beets table beets	broccoli cauliflower celery onions tomatoes	

Recommended amounts of molybdenum and zinc on organic soils when the pH of the surface layer is known.

Element	pH of surface layer		
	< 5.5	5.5-6.5*	>6.5
Molybdenum	0.3 lb/acre in band near seed or seed treatment, 1 oz. per bu. of seed	0	0
Zinc	0	0	2-3 lbs/acre for 2-3 years

*Soils high in iron also show a need for molybdenum. Use rate suggested for pH <5.5.

Potash fertilizer recommendations for organic soils based upon crop and soil test using the 1N ammonium acetate method

Available soil potassium Pounds of "K" per acre					Pounds K_2O per acre recommended
				80	600
				200	500
			80	300	400
		75	160	400	300
		140	220	450	250
	75	200	300	500	200
	150	250	350	560	160
50	200	300	400	620	130
100	250	350	450	700	100
150	280	380	480	750	80
200	310	410	510	800	60
250	350	450	550	825	40
275	375	475	575	850	20
300	400	500	600	900	0
barley blueberries grass oats rye pasture wheat	beans clover corn mint peas soybeans sudan grass sweet corn turnips	alfalfa asparagus cabbage carrots cucumbers lettuce parsnips radishes spinach	broccoli cauliflower onions potatoes sugar beets table beets tomatoes	celery	

Recommended amounts of manganese, boron and copper on organic soils, When the expected crop response is low, medium, or high and the pH of the surface lay is known.

Expected responses of a crop is shown on the next page.

Element	Expected response	pH of surface layer 5.0-	5.0-5.5	5.8-6.0	6.0-6.5	6.5-7.2	7.3-8.0
Manganese	high	0	0	10	10	20	40*
Mn	medium	0	0	5	5	10	20
	low	0	0	0	0	5	10
Place manganese in bands near the seed.							
Boron	high	3	3	3	5	5	5
Bo	medium	1	1	1	3	3	3
	low	0	0	0	1	1	1
Do not band Bo near the seed or the following, corn, barley, and beans, are frequently injured.							
Copper**	high	6	6	4	4	2	2
Cu†	medium	4	4	2	2	0	0
	low	2	2	0	0	0	0

†The pH for Cu recommendations is the native soil reaction; liming does not alter total Cu need.

* More practical to disc in 500 lbs. per acre of sulfur and use 20 lbs. per acre of manganese, unless free lime is present.

**No more than 20 lbs/acre and 40 lbs/acre of copper are needed for crops with low to medium response and high responses, respectively

Micronutrients: Relative responses of various crops to micronutrients and sodium on organic soils.

Relative responses of crops to micronutrients and sodium on organic soils.

Crop	Micronutrient element response			
	Manganese	Boron	Copper	Others
Alfalfa.................	low	high	high	
Asparagus...............	low	low	low	
Barley..................	medium	none	medium	zinc
Beans...................	high	none	low	zinc
Blueberries.............	low	none	medium	
Broccoli................	medium	medium	medium	molybdenum
Cabbage.................	medium	medium	medium	molybdenum
Carrots.................	medium	medium	high	
Cauliflower.............	medium	high	medium	molybdenum
Celery[1]...............	medium	high	medium	sodium[3] calcium[2]
Clover..................	medium	medium	medium	molybdenum
Cucumbers...............	medium	low	medium	
Corn....................	medium	low	medium	zinc
Grass...................	medium	none	medium	
Lettuce.................	high	medium	high	molybdenum
Oats....................	high	none	high	
Onions..................	high	none	high	zinc, molybdenum
Parsnips................	low	medium	medium	
Peas....................	high	none	low	
Peppermint..............		none	low	
Potatoes................	high	low	low	
Radish..................	high	medium	medium	
Rye.....................	none	none	none	
Spearmint...............	medium	none	low	
Soybeans................	high	none	low	
Spinach.................	high	medium	high	molybdenum
Sudan grass.............	high	none	high	
Sugar beets.............	medium	high	medium	sodium[3]
Sweet corn..............	medium	low	medium	zinc
Table beets.............	medium	high	high	sodium[3]
Turnips.................	medium	high	medium	
Wheat...................	high	none	high	

[1]Certain varieties need 5 to 10 pounds per acre of magnesium sulfate (epsom salts) applied to the foliage weekly.

[2]Calcium is needed to prevent blackheart disorder and is applied as calcium chloride at the rate of five to ten pounds per acre weekly.

[3]Sodium applied in the form of ordinary salt will help sugar beets, table beets, and celery, especially when the soil is low in available potash. It is, however, necessary to include potash in the fertilizer. Suggested rates of salt are 500 pounds per acre.

Water control: Organic soils must be artificially drained before they can be cultivated. In most places a system of open ditches 150 to 300 feet apart and tile lines are used. Ideally, the water table should be maintained about 30" below the land surface. This prevents drouthiness and decreases decomposition rate or subsidence of the organic soils and decreases the wind erosion hazard. In some places it has been possible to use a pumping system to lower the water table and make drainage feasible. Irrigation is commonly practiced on organic soils to increase yields of truck crops and decrease frost damage and wind erosion. Where tile drains are installed long tile (24 inches) help avoid poor alignment due to uneven settling. Back-filling with rawer peat, straw or marsh hay helps to prevent filling of the tile by fine material(or sand in group M/4c). Clay tile are preferable below a pH of 6.0. Tile should be installed 3 to 5 feet deep and spaced in accordance with the soil properties as indicated below:

Soil management group	Tile	
	Spacing	Depth
Mc	6 rods	4-5 feet
Mc-a	6 rods	4-5 feet
M/1c	3 rods	3-4 feet
M/3c	4-5 rods	3-4 feet
M/4c	Ditches may be adequate 24-36 rods	3+ feet
M/mc	4 rods	3-4 feet

and mineral soils with thin organic surface layers

Erosion control: Organic soils/are subject to wind erosion when cultivated. This may result in damage to seedlings, filling of drainage ditches and shortening the life of shallow organic soils. The hazard is greatest when the soil is loose and dry. Compacting the surface, maintaining a relatively high water table and irrigation avoid or alleviate these conditions. Strip cropping, buffer strips and windbreaks aid in preventing excessive erosion, White pine, Austrian pine, or green willow are suitable species. Spirea and multiflora rose can also be used but they lack height. Interplanted rows of grains such as wheat, barley or rye 2 or 3 feet apart can be used until next crop is big enough to protect the surface. In some cases, deep tillage to bring up more fibrous materials or roughen the surface have helped prevent erosion losses.

Frostiness: Maintaining a compact surface, a high water table, and use of sprinkler irrigation systems aid in preventing frost damage to crops and in decreasing wind erosion.

Other conservation practices: Avoid fires on organic soils. Water table control decreases rate of subsidence.

GROUPS Ra, Rc

Description: R (rocky) -- Very shallow loamy to sandy soils, underlain by bedrock at less than 18 inches from the surface. The bedrock may be sandstone or limestone.

Ra -- Well drained or moderately well drained.

Rc -- Imperfectly or poorly drained.

Management problems and suggestions: Because of the rockiness of these soils and their very shallow nature, they are not suitable for cultivated crops. Where cleared, they are commonly used for permanent pasture. Because of their shallowness, they have low water holding capacities and yields of pastures and timber are low. Where the bedrock is suitable, these areas may be valuable as quarries for limestone, gypsum, building stones, or abrasives. They have some value as wildlife and recreational areas.

GROUPS Sa, Sc

Sa -- Miscellaneous, well drained, non-agricultural land types. Includes borrow, clay, sand or gravel pits; lake beaches - sandy, gravelly, stony or rocky; dunes; madeland and steep gullied land. These areas are suitable for wildlife and recreational purposes. The beaches may be valuable water frontage for summer homesites, parks or resorts.

Sc -- Miscellaneous, imperfectly to poorly drained, non-agricultural land types. Includes lake marsh and wet swales. These areas are best utilized for water fowl, muskrats or other aquatic wildlife.

SOIL SERIES IN MICHIGAN AND THEIR SOIL MANAGEMENT GROUPS

Soil Series	Soil Management Group*
Aboite	1.5b
Abscota	L-4a
Adolph	1.5c
Adrian	M/4c
Ahmeek	3a-2
Alcona	3a
Algansee	L-4c
Alger	3a
Allendale	4/1b
Allowez	Ga
Alpena	Ga
Amasa	3a-a
Angelica	2.5c
Antrim	4a
Arenac	5/2b
Arvon	L-4c
AuGres	5a-H
AuTrain	5a-h
Bach	2.5c-c
Bannister	4/2c
Baraga	Ga
Barker	1.5a
Bark River	2.5a
Barry	3c
Belding	3/2b
Bellefontaine	3a
Bentley	4a
Bergland	1c
Berrien	5/2a
Berville	3/2c
Bibon	5/2a
Blount	1.5b
Blue Lake	4a
Bohemian	2.5a
Bonduel	3/Rc
Bono	1c
Bowers	1.5b
Boyer	4a
Brady	4b
Brant	4/2a
Breckenridge	3/2c
Brevort	4/2c
Bridgman	5.3a
Brimley	2.5b
Bronson	4a
Brookston	2.5c
Bruce	2.5c
Brule	L-2c
Burleigh	4c
Burt	2/Rc
Butternut	1.5c
Cadmus	3/2a
Capac	2.5b
Carbondale	Mc
Carlisle	Mc
Casco	4a
Cathro	M/3c
Celina	2.5a
Ceresco	L-2c
Champion	3a-a
Channing	5b-h
Charity	1c-c
Charlevoix	3b
Chassell	L-4c
Chatham	3a
Cheneaux	4b
Chesaning	4/2b
Chocolay	3a-a
Cohoctah	L-2c
Coldwater	3b
Coloma	4a
Colwood	2.5c
Conover	2.5b
Constantine	4a
Coral	3b
Coventry	3a
Crosby	2.5b
Croswell	5.0a
Crystal Falls	2/Ra
Dafter	3/1b
Danby	L-2c
Dawson	Mc-a
Deer Park	5.3a
Deford	4c
Detour	Gc

*Capital letters in first part of symbol: G = gravelly or stony soils;
L = lowland (Alluvial soils);
M = mucks and peats
R = rocky soils

Modifying symbols used after dash representing subgroups:

a = naturally very strongly acid soils
c = soils which are limy at or near surface
h = subsoils that are hardened and cemented.

Soil Series	Soil Management Group
Diana	Gc
Dighton	1.5a
Dillon	5c
Dowagiac	3a
Dresden	3a
Dryburg	3/2a
Dryden	3a
Duel	4/Ra
East Lake	5.0a
Eastport	5.3a
Eben	3b
Echo	5.0a
Edmore	4c
Edwards	M/mc
Eel	L-2a
Elmdale	3a
Elo	1.5a-a
Emmert	Ga
Emmet	3a
Ensley	3c
Epoufette	4c
Essexville	4/2c-c
Evart	L-4c
Ewen	L-2a
Fabius	4b
Fox	3a
Freesoil	3a
Froberg	1a
Fulton	1b
Gaastra	2.5b
Gagetown	2.5a-c
Gay	3c
Genesee	L-2a
Gilchrist	4a
Gilford	4c
Gladwin	4b
Glendora	L-4c
Glengary	L-2c
Gogebic	3a-a
Gormer	L-2c
Granby	5c
Graycalm	5.0a
Grayling	5.7a
Greenwood	Mc-a
Griffin	L-2c
Guelph	2.5a
Hagener	5.0a
Hessel	Gc
Hettinger	1.5c
Hiawatha	5.0a
Hillsdale	3a
Hodunk	3a
Houghton	Mc
Hoytville	1c
Huron	1a
Ingalls	4b
Ionia	3a
Iosco	4/2b
Iron River	3a-a
Isabella	1.5a
Jeddo	1.5c
Johnswood	3a
Kalamazoo	3a
Kalkaska	5.0a
Karlin	4a
Kawkawlin	1.5b
Kendallville	2.5a
Kent	1a
Kerston	L/Mc
Keweenau	4a-a
Kibbie	2.5b
Kinross	5c
Kiva	4a
Kokomo	2.5c
Lacota	3c
Landes	L-2a
Lapeer	3a
Latty	1c
Leelanau	4a
Lenawee	1.5c
Linwood	M/3c
Locke	3b
London	2.5b
Longlois	2.5a
Longrie	3/Ra
Lorenzo	4a
Loxley	Mc-a
Lucas	1a
Lupton	Mc
Mackinac	2.5b
Macomb	3/2b
Mancelona	4a
Mangum	4c
Manistee	4/2a
Marenisco	4a-a
Markey	M/4c
Marlette	2.5a

Soil Series	Soil Management Group
Matherton	3b
Maumee	5c
McBride	3a
McGregor	3b-c
Mecosta	L-4a
Melita	5/2a
Menominee	4/2a
Metamora	3/2b
Metea	4/2a
Miami	2.5a
Missaukee	3b
Montcalm	4a
Moran	3/Ra
Morley	1.5a
Morocco	5b
Moye	4b
Munising	3a-a
Munuscong	3/1c
Muskegon	L-2a
Mussey	4c
Nappanee	1b
Negaunee	3/Ra
Nekoosa	5.0a
Nester	1.5a
Newaygo	3a
Newton	5c
Nunica	1.5a
Oakville	5.0a
Ockley	2.5a
Ocqueoc	4/2a
Ogden	M/1c
Ogemaw	5b-h
Ogontz	3/2c
Omega	5.7a
Omena	3a
Onaway	2.5a
Onota	3/Ra
Ontonagon	1a
Orienta	5/2b
Oshtemo	4a
Otisco	4b
Ottawa	5/2a
Ottokee	4a
Palms	M/3c
Palo	3b
Parkhill	2.5c
Parma	3/Ra
Paulding	0c
Pelkie	L-2c
Pence	4a-a

Soil Series	Soil Management Group
Pennock	L-2c
Perrin	4a
Perth	1b
Pewamo	1.5c
Pickford	1c
Pinconning	4/1c
Pinora	L-2c
Plainfield	5.0a
Pleine	3c
Posen	3a
Randville	4a
Redridge	4b
Richter	3b
Rifle	Mc
Rimer	3/1b
Rodman	Ga
Rollin	M/mc
Ronald	3c
Roscommon	5c
Roselawn	5.3a
Roselms	0b
Rousseau	4a
Rubicon	5.3a
Rudyard	1b
Ruse	3/Rc
Saganing	4c
Sanilac	2.5b-c
Saranac	L-2c
Satago	3/Rc
Sauble	5.3a
Saugatuck	5b-h
Saverine	3/2b
Sebewa	3c
Selkirk	1b
Seward	3/2a
Shelldrake	5.3a
Shoals	L-2c
Sims	1.5c
Sisson	2.5a
Skanee	3b
Sleeth	2.5b
Sloan	L-2c
Spaulding	Mc-a
Sparta	5.0a
Spinks	4a
Stambaugh	3a-a
St. Clair	1a
St. Ignace	Ra
Strongs	5.0a
Summerville	Ra
Sumner	4a
Sunfield	3a
Superior	1a

Soil Series	Soil Management Group	Soil Series	Soil Management Group
Tahquamenon	Mc-a		
Tappan	2.5c-c		
Tawas	M/4c		
Teasdale	3b		
Tedrow	4b		
Thackery	2.5a		
Thomas	1.5c-c		
Tobico	5c-c		
Toledo	1c		
Tonkey	3c		
Traunik	5b		
Traverse	3b		
Trenary	3a		
Trout Lake	5b-h		
Tula	3b		
Tuscola	2.5a		
Twining	1.5b		
Tyre	4/Rb		
Ubly	3/2a		
Vilas	5.3a		
Volinia	3a		
Wainola	4b		
Waiska	Ga		
Wakefield	2.5a		
Wallace	5a-h		
Wallkill	L-2c		
Warners	M/mc		
Warsaw	3a		
Waseki	4b		
Washtenaw	L-2c		
Watersmeet	5b-a		
Watton	1.5a		
Wauseon	3/1c		
Wea	2.5a		
Weare	5.0a		
Westland	2.5c		
Wexford	5.0a		
Wheatley	5c		
Whittemore	1.5c-c		
Willette	M/1c		
Winegars	4b		
Winterfield	L-4c		
Wisner	1.5c-c		
Witbeck	3c		
Yalmer	4a-a		

GLOSSARY

ALLUVIUM: Mineral or organic materials deposited on flood plains by streams.

BLINDING: Hay or straw placed directly on tile before backfilling with evacuated materials.

BUFFER STRIP: Strips of protective crops such as small grains or sod to protect organic or sloping soils from wind erosion or water erosion, respectively.

CARRIER (FERTILIZER CARRIER): Fertilizer materials used to supply nutrients needed by crops.

CLAYEY: Includes all clay textural classes, i.e. sandy clay, silty clay, and clay.

COUNTY PLAT BOOK: A book of maps showing property boundaries and owners' names in a county.

CROP ROTATION: A sequence of crops that succeed one another in an order that is repeated periodically, eg. a sequence of corn, oats, wheat and clover that is repeated every four years.

EROSION CLASS: The groups into which soils are classified according to the severity of erosion that has occurred, eg. Class 1 - slightly eroded; Class 2 - moderately eroded; Class 3 - severely eroded.

FRAGIPAN: A compact loamy horizon that is very hard and brittle when dry and firm and fragile when moist. The fragipan may interfere with root and water penetration.

INDEX MAP: A map in a soil survey report which shows the location of all soil maps for that area.

LEAST PROTECTIVE CROPPING SYSTEM: The cropping system which gives the minimum allowable protection or permits the maximum relative soil loss for a given soil phase.

LOWLAND: Flat land adjacent to streams and rivers that is subject to periodic flooding.

MAPPING UNIT: All soil areas that are designated by a given symbol on a soil map.

MICRONUTRIENT: An essential element needed in minute quantities by plants.

MINIMUM TILLAGE: The least amount of tillage or seedbed preparation needed to obtain rapid germination, a good stand, and good yields of a given crop.

MOTTLING, SOIL: Spots, streaks, or splotches of color in soil materials, usually resulting from impeded drainage. The pattern of mottles are described by describing these colors and their degree of contrast as faint, distinct, or prominent.

MUCK: See Organic Soil.

NATURAL DRAINAGE: The relative degree of freedom from excess water in soils th throughout the year. Well drained soils may be planted earlier in the season than imperfectly or poorly drained areas. Artificial drainage is commonly needed on all but well drained and moderately well drained soils to insure satisfactory yields of most crop plants.

ORGANIC SOIL (MUCK AND PEAT): Soil in which organic materials (containing more than 20 to 30 percent organic matter by weight) dominate the properties of the upper foot or more of the profile. If the plant material in a layer or horizon of an organic soil is so completely decomposed that the plant structure can no longer be identified, the material is called muck. If the plant structure can still be identified, the material is called peat. Muck or peat when used in the soil type name refers to the plow layer.

ORGANIC MATTER: Dark colored soil material resulting from partial decomposition of plant and animal matter.

PARENT MATERIAL: The relatively unaltered, geological deposits that are similar to those from which at least part of the soil profile has developed.

PEAT: See Organic Soil.

PERMEABILITY: Relative rate at which water moves down through the soil.

pH: A scale used to express the relative acidity or alkalinity (reaction) of a soil horizon. Extremely acid soils have a pH less than 4.5, neutral soils a pH of 6.5-7.3; and very strongly alkaline soils 9.0 and above. The relative base status of the soil increases with the pH value.

PRODUCTIVITY: Productivity is the capacity of a soil to produce a given crop under a given environmental condition.

REACTION: The degree of acidity or alkalinity of a soil horizon as expressed in pH values or descriptive terms (see pH).

READILY AVAILABLE MOISTURE HOLDING CAPACITY: The amount of water held by a given soil after drainage that is easily available to plants.

SANDY: Includes all sandy textural classes, eg. sandy loams, loamy sands, and sands.

SLOPE CLASS: A range of slope percentages designated by a letter, eg. 2-6% are B slopes.

SOIL ACIDITY: See pH.

SOIL MANAGEMENT GROUP: A group of soil series that has similar management requirements and similar productivities when managed similarly.

SOIL MAP: A map designed to show the distribution of the various soils in the landscape.

SOIL PROFILE: A vertical section of soil showing two or more approximately horizontal layers or horizons.

SOIL SERIES: A group of soils closely similar in all respects except the characteristics easily recognizable at or near the surface such as texture, slope, degree of erosion, and stoniness. Soil series are given names of geographic features near which they were first described.

SOIL STRUCTURE: The arrangement of the individual soil particles into lumps, granules, or other aggregates.

Glossary (continued)

SOIL TEXTURAL CLASS: A range of percentages of sand, silt, and clay that are designated by a textural class name such as sandy loam.

SOIL TYPE: The soil type is commonly defined as a subdivision of the soil series. The name represents the soil series plus the texture of the surface or plow layer, for example, Capac loam.

STRATIFIED: Geologic material that has been deposited in layers with different properties such as texture, color, consistence, etc.

STRIP CROPPING: Strip cropping involves alternate strips of row crops with small grain and/or sod crops. On sloping areas subject to water erosion the strips commonly follow the contour of the land, contour strip cropping. On nearly level areas subject to wind erosion, the strips are arranged crosswise of the prevailing winds.

SUBSIDENCE: The lowering of an organic soil surface as the result of decomposition and dehydration.

SUBSOIL: Technically, the B horizon; commonly, that part of the soil profile below plow depth.

TAXONOMIC UNIT: Is a soil classification unit such as a soil type or a series. The names of the predominant soil classification unit is commonly used also as the name of the mapping unit. The mapping units commonly also contain varying minor proportions of other soils.

TEXTURE: See soil texture.

TILL (GLACIAL TILL): Unstratified glacial material that consists of clay, silt, sand, gravel, and boulders intermingled in various proportions. Deposited through action of glacial ice with little or no transportation by water.

UPLAND: All of the landscape above the alluvial flood plain or lowland level. See lowland.

WATER TABLE: Upper surface of the saturated zone at or beneath the earth's surface. The water level in a well protected from evaporation and removal of water.

WINDBREAK: A strip of trees or shrubs serving to reduce the force of the wind; any protective shelter from the wind.

HOW SOIL MAPS ARE MADE

Satisfactory soil maps can be made only by actually observing the soils in the field. Today the boundaries between the different kinds of soils are plotted on aerial photographs of the area by soil scientists as they walk across the fields systematically observing the soil characteristics not only at the surface but also at depths of 42 to 66 inches with the aid of soil augers. It is possible to make an accurate soil map on an area with a minimum of auger borings only when the relationships among the different soils present and the factors associated with their differences are known. Some of these relationships are discussed in the front of this circular and in somewhat more detail in Special Bulletin 402 -- Soils of Michigan -- of the Michigan Agricultural Experiment Station. Aerial photographs are a great aid in accurately drawing the boundaries between the different kinds of soils in an area. Many reference points (such as houses, fields, roads, and streams) are visible on the aerial photographs and many soil differences also show up because of the differences in the color of the soils or the crops growing on them at the time the photographs were taken. In Michigan, as in most other parts of the United States, the soils are being mapped cooperatively by the Soil Conservation Service of the U. S. D. A. and the State Agricultural Experiment Station. In addition, the U. S. Forest Service cooperates in the mapping of lands in National Forests. This cooperative endeavor is known as the National Cooperative Soil Survey.'

HOW SOILS ARE NAMED

Taxonomic units:

Each soil or taxonomic unit differs in the properties of one or more of its horizons or of the whole soil body, such as its shape, from every other unit. The soil series* name, the capitalized part of the soil's name, such as Marlette, stands for all the characteristics of the soil body used in the soil's classification except those that are easily observable at or near the surface of the land, such as the texture of the plow layer or the slope of the soil surface.

Differences within each soil series that are observable at or near the land surface are indicated by the short descriptive terms or phrases accompanying the series name. For example, Marlette loam, 6-12% slope, slightly eroded, is a Marlette soil with a loam surface, that occurs on slopes of from six to twelve percent, and has had a small part of its natural upper layers removed by erosion. The series name plus the texture of the surface soil is the soil type name.

Mapping units:

Each mapping unit, that is all areas on a soil map containing identical symbols, is composed predominantly of the soil or taxonomic unit (or units) mentioned in its name. In addition, other soils not practical or possible to separate (at the scale of the map used or in the time available for doing the work), are also present. Descriptions of each of the soils and mapping units in an area can be found in the published soil survey reports, where one is available.

*The soil series name is taken from some geographic feature (e.g. the name of a town, stream, township, etc.) near where it was first described. The Marlette series was named after the town in Sanilac County.

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APPENDIX H

A TEACHING PROGRAM

UNDERSTANDING SOIL MANAGEMENT GROUPS

A Teaching Program

Understanding Soil Management Groups

by

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A Teaching Program developed under the direction of:
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Preface

Instruction in soils is a vital part of needed instruction for students in vocational agriculture and conservation as well as for students in many related fields. Soil represents one of the most important basic resources of the nation. Appreciation of its importance and participation in wise use and conservation of the soil is essential to the welfare of the nation.

This paper is reproduced for use by teachers of agriculture and others to assist them in their instructional program in soils. The use of the scrambled book idea should provide an interesting device to students as they develop their understanding of the uses of soil.

Raymond M. Clark
Professor of Secondary Education
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OBJECTIVES OF THIS PROGRAM ON SOIL MANAGEMENT GROUPS

The overall objective of this program is to give interested individuals a working knowledge of the soil management group system of classifying soils as used in Michigan.

A. After completing the program you should be able to define and explain, in writing, all technical terms used in the program, such as texture, soil drainage, "two-storied" soil.

B. Determine the textural class of any soil, when given its percentage of sand, silt and clay, by referring to a texture triangle.

C. Be able to write the soil textures and natural drainage class for each management group when the management group symbol is given.

D. Be able to write the management group symbol if given a soil's average texture and natural drainage.

E. This program does not attempt to cover the kinds of soil management problems that occur in Michigan nor to make recommendations for the solution of these problems. This kind of information is available in the extension publication, "Know Your Soils and How to Use Them."

I. INTRODUCTION

Soil is one of man's most priceless possessions. It either directly or indirectly supplies most of the food, clothing and housing that are essential to the existence of the human race. Since soil is not unlimited in extent, nor a replaceable resource, it is essential that we use this resource wisely.

Much is known about the characteristics, potential uses and limitations of soil. For example, it is widely known that soil is not a uniform, homogeneous coating on the face of the land, but rather there are many "soils" that differ from each other and occur as patches on the landscape. Each patch adjoins others in the same way that pieces of a jig-saw puzzle fit together to form a complete picture. Each patch of soil is actually a three dimensional body with thickness as well as area just as is the puzzle piece. We will therefore call them soil bodies. If one digs a pit or examines a road cut within the patch he can observe the thickness of that soil which usually, in Michigan, is from two to five feet. Examination of the pit side or road cut should reveal that the soil has several distinct layers that tend to parallel the surface of the land. These layers are called horizons and a cross-section through all the horizons from top to bottom of the soil is called the soil profile.

The soil bodies, differ from each other because of differences in one or more of the five soil forming factors which control the development of soils. All of the soil bodies that have developed under identical factors of soil formation will have profiles that are the same. This makes it possible to classify or "group" soils on the basis of the properties of their profiles. All soils having the same kind of profile belong to one soil series.

Since all the soil bodies that belong to one soil series have the same kind of profile they can all be used in the same way, for example to grow the same crops, and be expected to give the same yields if managed alike. It is therefore possible to run experiments on a body of one soil series, for example on an experimental farm, and apply the results of the experiments to other bodies of that soil series such as those in farmers fields.

The problem with using soil series as a basis for soil management recommendations is that there are more series than are needed for any particular purpose. To work with all of them separately would make the cost in time and money prohibitive. The use of this information is simplified by grouping all series with similar profiles into groups called soil management groups. The series within each soil management group are sufficiently similar to permit the use of similar management recommendations with all of them.

This teaching program is intended to teach you what a soil management group is, how soils are classified into management groups, the system of connotative symbols used to designate these groups, and what information can be ascertained by interpretation of any soil management group symbol.

Instructions in the Use of This Teaching Program

Each statement preceded by an S 1, S 2, S 3, etc. is intended to teach you a new bit of information such as a term, a symbol, or a concept. After reading each statement proceed to the sentence containing blanks provided for you to write in the word, symbol, or information that best applies. Where the reply calls for one word there will be one space in which to write it, two words have two spaces etc. The statement and reply are referred to as the "stimulus" of a teaching program. The correct answer to the stimulus, called the "response", is given just preceding the next stimulus and is labeled R1, R2, R3, with the "R" numbers corresponding with the "S" numbers. If your reply is incorrect return to the statement for which it was made and determine why you made the mistake, then proceed to the next stimulus. The stimulus and its response constitute one "frame" of the teaching program.

This program is separated into three sections with a quiz given at the end of each to allow you to determine whether you have mastered the material. Instructions for review are given if you do not attain a satisfactory level of comprehension.

This program is for your benefit and it is to your disadvantage to "look ahead" to the correct responses to the reply section of each frame. If you find yourself tempted to do this cover the response with a card until you have completed your reply. You are free to work at your own speed and at any time that it is convenient. After successfully completing this program you will have a working knowledge of the soil management group classification of soils as used in Michigan. This will be very useful to you in understanding and using information dealing with soil management.

S1 A soil management group is a group of soil series that are sufficiently similar to be managed alike.

A group of soil (a) _______ similar enough to be managed alike is called a soil (b) ______________ ______________.

R1 (a) series (b) management group

S2 All soils may be classified into one of the following classes; the organic soils or the mineral soils. Organic soils, in general, contain more than 20% organic matter in the upper foot of soil.

Soils containing more than 20% organic matter are classified as (a) ______________ soils.

R2 (a) organic

S3 Conversely most soils that contain less than 20% organic matter or more than 80% mineral material in the upper foot are classified as mineral soils.

Soils containing less than 20% organic matter are classified as (a) ______________ soils.

R3 (a) mineral

S4 The organic soils were formed from the accumulation of partially decomposed plant remains in shallow lakes or swamps and are therefore naturally very poorly drained soils.

The natural drainage of organic soils is (a) ____________ ________.

R4 (a) <u>very poor</u>

S5 Mineral soils occur in one of the following natural soil drainage classes: well drained, moderately well drained, imperfectly drained, poorly drained, and very poorly drained.

The naturally best drained mineral soils occur in the (a) ________ __________ drainage class.

R5 (a) <u>well drained</u>

S6 The naturally well drained soils have "bright" brown or yellow subsoils and are the first to be dry enough to plant in the spring.

Soils that have the brightest colored subsoils and can be plowed the earliest in the spring are (a) ________ drained soils.

R6 (a) <u>well</u>

S7 In the soil management classification system all well drained soils are denoted by the letter "a".

The letter (a) ______ represents well drained soils in the soil management classification.

R7 (a) "a"

S8 Flat or depressed topographic positions are locations where runoff water from higher adjacent areas tends to accumulate. Very poorly drained soils are most likely to develop in these positions.

The natural drainage of soils developed in flat or depressed topographic positions is often (a) ________ __________ drained.

R8 (a) very poorly

S9 Very poorly drained soils typically have dull grayish subsoils with some orange or olive mottles below the nearly black surface soil.

Very poorly drained soils can be recognized by their nearly (a) _________ colored surface horizon and the dull (b) ________ colored subsoil.

R9 (a) black

(b) grayish

S10 Very poorly drained soils generally have a nearly neutral surface layer and therefore do not need lime for agricultural crop production.

Crop production is not dependent on the application of (a) ________ to very poorly drained soils, because they are usually nearly neutral in the surface horizon.

R10 (a) lime

S11 The most serious agricultural limitation of naturally very poorly drained soils is their wet condition throughout most of the year.

Most agricultural crops will not grow on very poorly drained soils because they are too (a) ____________.

R11 (a) wet

S12 The limitation of wetness can be corrected by installing a drainage system.

Excess wetness can be corrected by the use of (a) ________ _________.

R12 (a) drainage system

S13 Very poorly drained soils are assigned the letter "c" in the soil management group classification.

Very poorly drained soils are in soil management group (a) _______.

R13 (a) "c"

S14 Naturally well drained and naturally very poorly drained soils are the two extremes of the soil drainage classes. Imperfectly drained soils are intermediate in drainage between these two extremes.

(a) _______________ drained soils are intermediate among the soil drainage classes.

R14 (a) imperfectly

S15 Imperfectly drained soils are assigned the letter "b" as their soil management group drainage designation.

The letter (a) ________ represents imperfectly drained soils.

R15 (a) "b"

S16 Moderately well drained soils are slightly wetter than well drained soils but are included with them in the management group drainage class and therefore are also designated by an "a"

Moderately well drained soils have the management group drainage class designation (a) ________.

R16 (a) "a"

S17 The last of the five natural soil drainage classes includes poorly drained soils. Poorly drained soils are slightly better drained than the very poorly drained ones but are grouped with them as having "c" drainage in the soil management groups.

The soil management group drainage designation for poorly drained soils is (a) ________.

R17 (a) "c"

S18 Now for a short review to see if you have learned your a, b, c's of the soil management group system of classifying natural soil drainage.

Write the soil management group drainage designation for each of the following natural drainage classes.

(1) well drained ______

(2) very poorly drained ______

(3) moderately well drained ______

(4) imperfectly drained ______

(5) poorly drained ______

All organic soils are included in the soil management drainage group (6) ______, while mineral soils may belong in one of the three following soil management drainage groups (list in order from best to poorest drainage classes). (7) ______, (8) ______, (9) ______.

R18 (1) "a"

(2) "c"

(3) "a"

(4) "b"

(5) "c"

(6) "c"

(7) "a"

(8) "b"

(9) "c"

If you missed more than two of the questions, one through nine, you should rework the program from the beginning. If you missed two or less you may continue with the next section of this program.

II. Soil Texture

The mineral particles in soil vary in size. The smallest particles are submicroscopic in size, that is too small to be seen individually under an ordinary microscope. These particles belong in the group that are less than .002 millimeters in diameter and are classified as the clay fraction. When wet soil material composed largely of clay particles feels "greasy".

Mineral particles that are large enough to be seen individually under a microscope but which are too small to be seen by the naked eye are silt particles and fall in the size range of .002 millimeters up to .05 millimeters in diameter. A sample of moist silt feels soft like cake flour when rubbed between your fingers.

Mineral particles larger than silt (.05mm) but less than 2 millimeters in diameter are sand grains. A moist sample of sand feels "harsh" or gritty", and the individual grains can be seen without the aid of a microscope. Fragments larger than sand are gravel, stones or cobbles, and boulders.

Nearly all mineral soils contain a mixture of sand, silt and clay fractions. Different proportions of these three size fractions are represented by different soil textural classes. These texture classes apply to the fine earth portion which passes thru a screen with openings 2 mm in diameter. This triangle can be simplified by making the base line and equal sand lines solid, the left side and horizontal lines dashed, and the right side and remaining diagonals dotted lines.

In order to make it easy for you to understand the meaning of soil textural classes turn to page 17 which contains a "texture triangle" on which all of the soil textural classes are shown as areas within the triangle.

S19 Any point within the triangle represents the percentages of sand, silt and clay of the fine earth from a soil sample. Their total is always 100%.

The texture of a soil sample is represented by a (a) ___________ within the texture triangle.

R19 (a) point

S20A Note that the base of a triangle represents the percentages of sand that vary from 0% on triangle on the right to 100% on the left. The percentage of sand is marked at 10% intervals along the solid base line of the triangle.

The center of the base line of the texture triangle represents

(a) _________% (b) __________.

R20A (a) 50%

(b) sand

R20B The remainder of the sample represented by the mid-point of the base of the triangle is composed of silt. Since the base is also the zero clay content line.

The mechanical composition of the sample represented by the mid-point of the base of the texture triangle is (a) ________% sand and

(b) __________% silt giving a total of (c)____________%.

S20B (a) 50% sand (b) 50% silt (c) 100%

S21 The left side of the triangle represents the percentages of clay that range from 0 at the bottom to 100% at the top and the right side of the triangle represents the percentages of silt ranging from 0 at the top to a 100% at the bottom of that side. Percentages of clay and silt are indicated at 10% intervals along the dashed and dotted sides of the triangle, respectively.

The upper corner of the triangle represents (a) ________% clay and (b) ______% silt.

R21 (a) 100% clay

(b) 0% silt

S22 The textural class of a soil sample may be determined by doing the following steps:

(1) Get data from a mechanical analysis that gives the percentages of sand, silt and clay in your soil sample.

(2) Locate the percentage of sand on the base line of the triangle and follow the line representing that percentage upward toward the left along the solid lines representing equal sand contents in the triangle.

(3) Find the percentage of clay on the left side of the triangle and follow this percentage line across the triangle parallel to the bottom, along lines of equal clay content. Where these two lines intersect you have the texture of this sample.

(4) Find the percentage of silt on the right side of the triangle and follow its percentage line downward to the left. This line should intersect the clay and sand line at the point you located earlier. If not an error has been made.

(5) The point at which these three lines intersect is the texture of your sample. Its textural class is printed within the dark-line bordered area containing your point.

Using your textural triangle and the steps outlined above determine the textural class of a sample containing 30% sand, 30% clay, and 40% silt. (a) ______ ______.

R22 (a) clay loam

S23 Using the procedure you did on the previous page, practice finding the textural classes for the following sample analysis.

	% sand	% clay	% silt	answer
(a)	20	20	60	______ ______
(b)	50	10	40	______________
(c)	20	50	30	______________
(d)	65	15	20	______ ______
(e)	20	80	0	______ ______

R23 (a) silt loam

(b) loam

(c) clay (Note that the term clay is used both as one of the three size fractions and as a textural class).

(d) sandy loam (Notice that you can estimate % numbers between these values written at the edge of the triangle).

(e) fine clay (as in the first case this sample contains only 2 of the 3 size fractions and when this is true the textural class occurs on one edge of the triangle. Samples containing only 1 size fraction are at the corners of the triangle and all other possible combinations of the three fractions are points inside the triangle.)

S24 The following is a short review so that you can determine whether you have comprehended what is meant by soil texture and how to determine soil textural class using mechanical analysis data and the soil texture triangle.

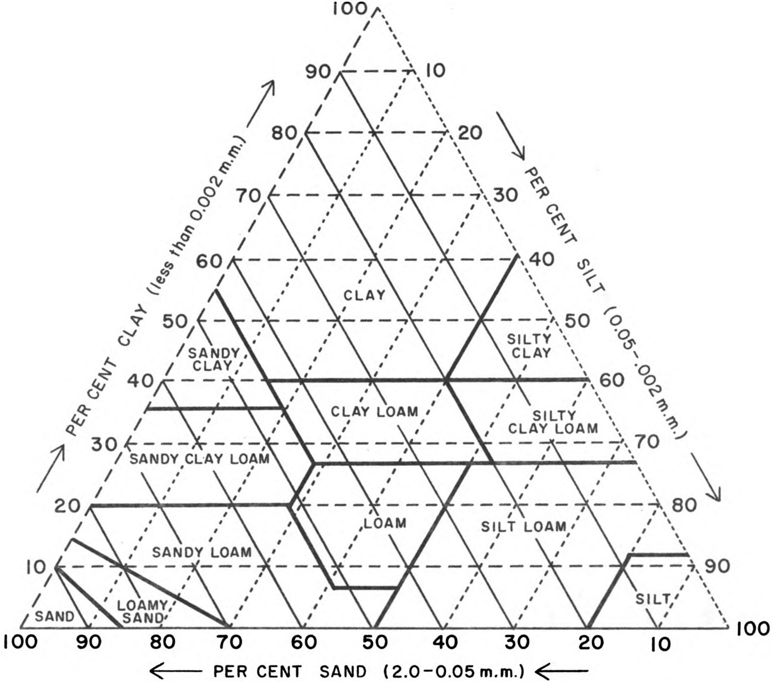
Most soil samples contain 3 sizes of particles which are from the largest to the smallest: (1) ________, (2) ________, (3) ________. These particles occur in various proportions and any sample can be represented by a (4) ________ on the texture triangle. This point falls within an area that is bounded by dark lines and is called a (5) ______ ______. To determine the textural class of a sample the percentage of sand is read on the (6) ________________ of the textural triangle, the percentage of clay is read on the (7) __________ side of the triangle and the percentage of silt is read on the (8) ___________ side.

Use the texture triangle to determine the textural class of each of the following samples.

	% sand	% clay	% silt	answer
(9)	30	30	40	_______ _______
(10)	55	30	15	_____ _____ _____
(11)	0	35	65	_____ _____ _____

R24 (1) sand (2) silt (3) clay (4) point (5) textural class (6) base or bottom (7) left or dashed (8) right or dotted (9) clay loam (10) sandy clay loam (11) silty clay loam

If you missed more than two of the questions, one through eleven, you should rework the program from the beginning of the section on texture p. 12 If you missed two or less you may continue with the next section of this program.



THE TEXTURAL TRIANGLE, SHOWING THE COMMON SOIL CLASSES

III. Textural Classes and Complete Symbols of Soil Management Groups

Earlier in the program it was pointed out that soil management groups are groups of soil series that can be managed similarly. One of the characteristics on which this grouping is made is the natural drainage of the soil series. As you remember, well and moderately well drained soils are classified in the (a) management groups; imperfectly drained soils in the (b) management groups; and the poorly and very poorly drained soils in the (c) management groups. The second characteristic used to classify series into managmment groups is the average textural class of the profile of the series, that is to say, if we average the textural classes of all the horizons of a soil series and refer to this average as the "average texture of the profile" it is possible to classify the series on this basis. In Michigan the average textural class of the profile of a series is usually the same as the textural class of the underlying "parent material" of the soil, if it was developed from an initially uniform material.

S25 The number "1" is used to designate the management group that contains soil series with clay and silty clay textured profiles, and the number "0" is used for profiles with "fine clay" textures.

Soil series with clay and silty clay textured profiles belong in the (a) ______ management group and those with "fine clay" profiles belong in the (b) _______ management group.

R25 (a) "1"

(b) "0"

S26 Soils with clay loam, silty clay loam, loam or silt loam, are grouped together in the soil management group "2".

Loam textured soil profiles belong in management group (a) ________.

R26 (a) "2"

S27 Soil management group "3" contains soil series with sandy loam textured profiles.

Soils with sandy loam textured parent material belong in soil management group (a) ____________.

R27 (a) "3"

S28 Soils with loamy sand textured profiles belong in the "4" soil management group.

Soil management group (a) _______ contains series with loamy sand textured profiles.

R28 (a) "4"

S29 The coarsest textured soil management group is group "5" which contains series with sand textured profiles. These are subdivided on a basis of their relative droughtiness with 5.0 being drouthy, 5.3 being very drouthy and 5.7 being extremely drouthy.

Very drouthy soils with sand textured profiles are given a soil management group number (a) ________.

R29 (a) (5.3)

S29B One of the advantages of this system of designating the soil management groups is its flexibility to accomodate additional differentiations as they are needed. Recently it has been found necessary to sub-divide the two groups into its finer and coarser components. These are numbered 1.5 and 2.5 respectively.

The well drained and poorly drained series in the finer textures are the (a) ________ ________ and (b) ________ ________ groups.

R29B (a) 1.5a

(b) 1.5c

Earlier in the program you learned your a, b, c's of the soil management group drainage classes. Now you have just covered 1, 2, 3's of soil management group textures which proceed from the finest to the coarsest with "0" representing fine clay; "1" representing clay and silty clay; "2" representing clay loam, silty clay loam, loam, and silt loam; "3" representing sandy loam; "4" representing loamy sand; and "5" representing sand with 5.0, 5.3 and 5.7 degrees of increasing drouthiness.

Each management group developed from uniform mineral materials consists of a number representing its profile texture and a letter representing its natural drainage. The following is a simplified chart showing the basic texture and drainage combinations of mineral soils in Michigan.

Table 1. Relationships among soil management groups with the connotative symbols of each group.

	MINERAL SOILS					
	Drainage (natural)					
Average texture of soil material or profile.	Well and moderately well drained		Imperfectly drained		Poorly and very poorly drained	
UPLANDS:	a		b		c	
Fine Clay, 0	0a		0b		0c	
Clay or silty clay, 1	1a		1b		1c	
		1.5a		1.5b		1.5c
Clay loams or loam, 2	2a		2b		2c	
		2.5a		2.5b		2.5c
Sandy loam, 3	3a		3b		3c	
Loamy sand, 4	4a		4b		4c	
Sands, drouthy, 5.0	5.0a		5b		5c	
very drouthy, 5.3	5.3a					
extremely drouthy, 5.7	5.7a					

S30 Using Table 1, fill in the information called for in the following question.

S30A Insert the proper symbol for each of the following:

(1) An imperfectly drained sandy loam soil ___________.

(2) A soil with an average profile texture of silty clay and very poor natural drainage __________.

(3) An extremely drouthy sand soil with good drainage ___________.

R30A (1) <u>3b</u> (2) <u>1c</u> (3) <u>5.7a</u>

S30B Give the natural drainage and the profile texture represented by each of the following symbols, using Table 1.

(4) 3c______________________________

(5) 2b______________________________

(6) 5.3a____________________________

R30B (4) <u>poor to very poorly drained sandy loam</u>

(5) <u>imperfectly drained clay loam or loam</u>

(6) <u>well drained, very drouthy sand</u>

In Michigan there are numerous so called "two-storied" soils. These soils have been formed from the deposition of two kinds of materials, one on top of the other. In general, the upper of the two deposits is less than 42 inches thick but more than 12 to 18 inches thick. One example is a sand water sorted sand deposit overlying a clay deposit. A second kind of two-storied soil is caused by a deposit of peat or muck over mineral material. The symbol used for "two-storied" soil is written as a fraction with the composition or texture of the upper story given in the numerator and the texture of the lower story given in the denominator.

S31 A "two-storied" soil with 36 inches of sandy loam over loam with good natural drainage would be written as 3/2a.

3/2a is a soil management symbol for a (a) ______ __________ soil. The upper story would have a (b) _________ _________ texture, the lower story a (c) _________ texture, and the soil would be naturally (d) __________ drained.

R31 (a) <u>"two-storied"</u>

(b) <u>sandy loam</u>

(c) <u>loam</u>

(d) <u>well</u>

S32 A new symbol (M) is used to designate muck or peat which are two kinds of organic soils which were described earlier in this program. They are always naturally very poorly drained and therefore carry the (c) drainage symbol.

Muck or peat that is 12-42 inches thick is considered a "two-storied" soil with the underlying mineral material being the lower story. Write the appropriate symbol for a soil having 36 inches of muck over clay. Remember that this symbol must include the upper story, the lower story and the natural drainage class. Symbol (a) ________.

R32 (a) <u>M/lc</u>

S33 In some situations muck or peat is underlain by a layer of soft limey material called marl which is given the symbol (m). This only occurs in a "two-storied" soil symbol where muck or peat less than 42 inches thick overlays the marl.

Using any of the above information write the symbol for muck 36 inches thick over marl. (a) ______________.

R33 (a) <u>M/m c</u>

S34 Another symbol that we have not previously used is "R". It is used to represent bedrock within 18 inches of the surface. If bedrock is below 18 inches but above 42 inches it becomes part of a fractional symbol.

An imperfectly drained "two-storied" soil with 36 inches of loamy sand over bedrock has the symbol (a) ________ for the upper story, (b) ________ for the lower story and the symbol (c) ________ for the drainage. These would be written as the complete management group symbol (d) ____________.

R34 (a) "4" (b) "R" (c) "b" (d) 4/R b

S35 Soils that are found on lowlands adjacent to streams or rivers and that are subject to flooding are given the special symbol "L". The L is written directly preceding the number and letter that represents the texture and drainage.

The symbol used to represent lowlands is (a) ____________.
The symbol for a well drained loam textured lowland soil is (b) ______.

R35 (a) "L" (b) L2a

S36 Soils that are very stony, cobbly or gravelly, are given the management group symbol "G".

A very gravelly soil with imperfect drainage has the management group symbol (a) ________.

R36 (a) Gb

S37 The special symbol (Sa) is used for lake beaches, bluffs or dunes and (Sc) for lake marshes and wet swales.

The letter (a) __________ is used as a special symbol for non-agricultural area. The drainage symbols (b) __________ accompanies it for lake marshes and (c) __________ accompanies it for beaches, bluffs or dunes.

R37 (a) "S"

(b) "c"

(c) "a"

Table 2. Relationships among soil management groups with the connotative symbols for each group.

Average texture of soil material or profile in mineral soils and character of organic materials	MINERAL SOILS — Drainage (natural) — Good and Mod. good (a)	Imperfect (b)	Poor to very poor (c)	ORGANIC SOILS M — Very poorly drained — Shallow, 12-42" thick (c)	Deep, 42" thick (c)
UPLANDS:					
Fine clay, 0	0a	0b	0c		
Clay or silty clay, 1	1a	1b	1c	M/1c	
Clay loams or loam, 2	2a {1.5a, 2.5a}	2b {1.5b, 2.5b}	2c {1.5c, 2.5c}		
Loam to sandy loam, over bedrock at 18-42", 2/R	2/Ra	2/Rc	2/Rc		Mc
Sandy loam, 3	3a	3b	3c		
Sandy loam over clay to silty clay at 14-42", 3/1	3/2a	3/1b	3/1c	M/3c	
Sandy loam over clay loams to loam at 18-42", 3/2	3/2a	3/2b	3/2c		
Loamy sand to sand over clay to silty clay at 18-42", 4/1	4/2a	4/1b	4/1c	——	or
Loamy sand to sand over clay loam to loam at 18-42", 4/2	4/2a	4/2b	4/2c		
Sand to loamy sand, 4	4a	4b	4c		
Loamy sands to sands over bedrock at 18-42", 4/R	4/Ra	4/Rb	4/Rc	M/4c	
Sands, drouthy, 5.0	5.0a	5b	5c	or	Mc-a[2]
very drouthy, 5.3	5.3a,5a(h)[1]	5b(h)[1]			
extremely drouthy, 5.7	5.7a			Mc-a[2]	
Sands over loam to clay at 42-66", 5/2	5/2a	5/2b	5c	——	
Stony, cobbly or gravelly, G	Ga	Gc	Gc		
LOWLANDS, ALLUVIAL SOILS, L:					
Moderately fine to moderately coarse textured	L2a	L2c	L2c		
Coarse textured	L4a	L4c	L4c	——	
MUCKS OR PEATS, M,					
0-42 inches of muck over marl			M/mc	M/mc	Mc
Rocky, bedrock at 18", R	Ra	Rc	Rc		
Special or miscellaneous, S					
Lake beach, bluffs or dunes	Sa	Sc	Sc		
Lake marsh and wet swales			Sc		

1. Subsoil cemented with humus and iron oxides.
2. Formed in extremely acid woody and fibrous or fibrous organic materials.

This completes the management group symbols that you should learn. The full list of those used in Michigan, their relationships and a few special symbols are given in Table 2. You are not expected to memorize depth limits but you are expected to know the textural classes included in each of the management group textures from 0-5, the drainage classes from a to c, and the symbols for organic soils, lowland soils, gravelly soils, rocky soils, and special areas commonly adjacent to lakes.

S38 The following is a short quiz to see if you have learned the symbols used in soil management groups. You should be able to write the symbol for a texture, drainage or special feature and vice versa.

Give the management group symbol for each of the following profile textural classes.

(1) loamy sand ________

(2) clay loam ________

(3) loam ____________

(4) sandy loam _______

(5) sand, very drouthy _______

Give the natural drainage and texture for each of the following soil management symbols.

(6) 1b ______________________________________

(7) 5.7a ____________________________________

(8) 4c ______________________________________

Give the soil management symbols for the following soils.

(9) "Two-storied" imperfectly drained soil with 30 inches of loam textured material over loamy sand. ________

(10) 18 inches of muck over clay. ________

(11) A poorly drained gravel soil. ________

(12) A well drained loam textured alluvial soil. ________

(13) An imperfectly drained soil with 24 inches of loamy sand over bedrock. ______

(14) 18 inches of muck over marl. ______

(15) The symbol for lake marsh. ________

Describe the soil natural drainage and average profile texture represented by the following management group symbols.

(16) 4/2a ________________________________

(17) L4c ________________________________

(18) M/4c ________________________________

(19) 2/Ra ________________________________

R38 (1) 4 (2) 1.5 (3) 2.5 (4) 3 (5) 5.3

(6) imperfectly drained clay

(7) extremely drouthy well drained sand

(8) poorly or very poorly drained loamy sand

(9) 2/4b (10) M/1c (11) Gc (12) L2a

(13) 4/Rb (14) M/mc (15) Sc

(16) well drained loamy sand over loam or clay loam

(17) poorly drained alluvial (lowland) loamy sand or sand.

(18) Muck over loamy sand or sand, very poorly drained

(19) well drained sandy loam or loam over bedrock

If you have missed 6 or more of these questions review Tables 1 and 2, then retake the test.

SUMMARY

It is becoming increasingly essential that we use our soils wisely in order to supply the tremendous amounts of food, clothing, and housing needed for an ever increasing population. Wise use of soils depends on the recognition that soils differ and an appreciation of the significance of these differences. Soils occur as contiguous distinct bodies having three dimensions. These soil bodies are grouped into soil series on a basis of similarity of profiles. The series can be further grouped into soil management groups on a basis of texture and natural drainage. All soils within one management group can be treated alike insofar as some agricultural management practices are concerned. For other practices the well drained groups need to be subdivided into slope and erosion classes. These subdivisions of the soil management groups are called soil management units or land capability units.

The management groups are represented by a system of connotative symbols. The basic symbols consist of a number representing the average profile texture and a letter representing the natural drainage of the soils within one management group. Aside from these basic symbols, capital letters are used to designate special conditions. "Two-storied" soils are shown by a fraction in which the number in the symbol in the numerator represents the material of the upper story and the symbol in the denominator represents the material of the lower story. The natural drainage of the soil is indicated with all these symbols by a succeeding small letter.

The soil management groups and their subdivisions into units are used extensively in Michigan as a basis for agricultural management and conservation recommendations. A wealth of information regarding use and interpretations of soil management groups can be found in the extension publication "Know Your Soils and How To Use Them."

FINAL SELF-TEST

The following is a short self-test by which you can determine whether you have attained the objectives as stated at the beginning of this program. Answer all questions then turn to page 32 for the correct answers. If you miss 4 or fewer questions you have demonstrated a satisfactory level of comprehension of the material in this program. If you miss more than 4,review those sections in which you are seriously deficient. (That is sections in which you missed 2 or more questions).

A. Define or explain each of the following terms as used in this program.

1. soil drainage ____

____

____

2. soil texture ____

____

____

3. soil management group ______________________________________

____

____

4. organic soils ____

____

____

5. soil management units ______________________________________

____

____

B. Use the textural triangle p. 17 to determine the textural class of soil samples with the following percentages of sand, silt and clay.

	% sand	% clay	% silt	answer
5.	40	20	40	____________
6.	40	30	30	____________
7.	15	15	70	____________
8.	0	45	55	____________

C. Write the natural drainage and profile texture (s) for each of the following soil management groups.

9. 3a ____

10. 4/2c ____

11. 4/Ra ____

12. M/mc ____

D. Write the management group symbol for each of the following management groups.

13. imperfectly drained clay ____________

14. sand dunes ____________

15. poorly drained loam over sand ____________

16. muck over sandy loam ____________

FINAL SELF-TEST ANSWERS

A. Your answers need not be exactly the same as those given below but they should contain the same general idea, (s).

1. Soil drainage as used in this program refers to internal drainage and is exhibited by the color of the soil profile associated with the earliness or lateness in the spring that the soil is sufficiently dry for tillage operations.

2. Soil texture refers to the proportions of sand, silt and clay in the fine earth of the soil sample as defined in the texture triangle.

3. Soil management group is a group of soil series that are sufficiently similar to be managed alike for some purposes.

4. Organic soils are soils containing, in general, more than 20% organic matter.

5. Soil management units are subdivisions of the soil management groups, particularly the well drained ones, commonly based on differences in slopes of the land surface and degree of erosion.

B. Soil textural classes.

5. loam
6. clay loam
7. silt loam
8. silty clay

C. Drainage and texture of soil management groups.

9. well drained sandy loam
10. poorly drained loamy sand over loam
11. well drained loamy sand over bedrock
12. very poorly drained muck over marl

D. Management group symbols.

13. 1b 14. Sa 15. 2/5a 16. M/3c

APPENDIX I

SOIL MANAGEMENT PROBLEM

NAME____ DATE ____________________________

On the attached soil map and using the "Know Your Soils" Leaflet:

I. Locate the following tract and bound it with a pencil line: T_____ N, R_____E, Sec. _____, _____40 of _______ 160 in _______________________

II. Fill out the following table completely for the tract in I.

Mapping unit symbol	Soil Name	Soil Management Unit		
		Soil management group	Slope class	Erosion class

III. Indicate for the sandiest, most sloping, best-drained soil management unit, what would be:

(1) Its mapping unit symbol - ______________________________

(2) Its lime requirement per acre for seeding alfalfa if its surface pH is 5.5 and the plow layer is 9 inches thick. ________ T/A. (Ignore the soil management group column in table 3 of Lime Bulletin)

((3) The fertilizer nutrients needed if the soil test shows 40 lbs. of P and 120 lbs. of K (using 1 N NH_4Ac, in the State Lab.)

____

IV. What yield of alfalfa would you expect on the soil in III) with the recommendations you have given? ______________________________
What fertilization is needed annually to maintain satisfactory yields? ______________________________________

V. If no artificial drainage has been supplied to this forty acres, is any required for success of the alfalfa seeding?___________ If so, on what soil management group, or groups is drainage needed most?_____________
How would the expected crop yields on this soil, after drainage, compare to the one in III above? ______________________________

VI. Of what would minimum tillage consist for corn on the soil in III above? ______________________________

VII. With the soil in III above:

(1) What is the largest C value of the cropping systems recommended, with up and down slope tillage on this soil?______________

(2) What is the cropping system with the highest C value that meets this standard with minimum tillage, no residues and the yields expected? ______________________________

(3) How large could the C value recommended be with more intensive erosion control pracitces?______________________________
What cropping system would meet this recommendation with minimum tillage, no risidues and the yields expected? ______________

VIII. What are the principal differences between the soils in III and V above? ______________________________
____
____
____
____

Where would you expect to fine each in the landscape?______________
____
____
____
____

VITA

The author was born April 4, 1923 near Medford, New Jersey. He attended elementary school at Lumberton and the first two years of secondary school at Mt. Holly, New Jersey. During the junior and senior years he attended Westtown Friends School and graduated in June 1941. He farmed from 1941 until September 1949 then entered Earlham College at Richmond, Indiana. In June 1953 he received a Bachelor of Science degree from Earlham and in September enrolled in the Graduate School of Cornell University as a candidate for the Degree of Master of Science. In August 1955 he returned to Earlham College to teach for a year. He married Elizabeth Haines in June 1956. In June he resumed studies at Cornell University and in January 1957 was offered a temporary teaching instructorship. On May 7, 1958 a son, Robert T., joined the Pennock family. The author completed the Master of Science Degree in September 1958 and accepted a position as Assistant Professor of Agricultural Production at the New York State University, Agricultural and Technical Institute, at Farmingdale. After teaching a wide range of agricultural courses there he was awarded a National Science Foundation Science Faculty Fellowship in June 1961. The following September he enrolled in the Graduate School of Michigan State University as a candidate for the Doctor of Philosophy Degree in Soil Science. Mary H. was a welcome addition to the Pennock family in June 1962. August 1964 he accepted a position as assistant professor of Agronomy at The Pennsylvania State University. He was awarded the Brundage Award for improvement of teaching in 1966 at The Pennsylvania State University. He was elected a member of Sigma Xi in June 1967. He has accepted a position with the Pennsylvania State University AID program in Poona, state of Maharashtra, India starting August 1967.