



This is to certify that the

thesis entitled

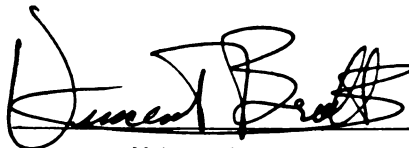
SELECTION OF A MODEL FOR PREDICTING
WORKING DAYS FOR FIELD OPERATIONS
IN THE SOUTH COAST OF PUERTO RICO

presented by

Carlos I. Semidei

has been accepted towards fulfillment
of the requirements for

M.S. degree in ATM
Department of
Agricultural Engineering



Major professor

Date July 23, 1993

LIBRARY
Michigan State
University

PLACE IN RETURN BOX to remove this checkout from your record.
 TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

SELECTION OF A MODEL FOR PREDICTING WORKING DAYS
FOR FIELD OPERATIONS IN THE SOUTH COAST OF PUERTO RICO

By

Carlos I. Semidei

Volume I

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Agricultural Technology and System Management
Department of Agricultural Engineering

1993

ABSTRACT

SELECTION OF A MODEL FOR PREDICTING WORKING DAYS FOR FIELD OPERATIONS IN THE SOUTH COAST OF PUERTO RICO

By

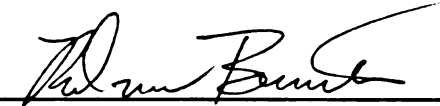
Carlos I. Semidei

Models developed by Tulu et al. (1974), Hunt (1986) and Babeir et al. (1986) were modified and evaluated for the prediction of field operations working days for different locations on the south coast of Puerto Rico. The model developed by Hunt (1986) was recommended as the best due its simplicity, sensitivity, accuracy, and input data required. This modified model was used to prepare probabilities of working day tables using sixteen years of weather data.

Tillage and non-tillage operations on vegetable production were evaluated. Sugarcane harvesting operation was not evaluated due to insufficient data.

Approved: 

Major Professor

Approved: 

Department Chairperson

To my wife Zulma, my son Carlitos, and my mother Elba.

ACKNOWLEDGMENTS

I would like to gratefully acknowledge the assistance of my guidance committee chairperson, Dr. Vincent F. Bralts, whose extensive support and trust has made this research possible. Special appreciation goes to Dr. Thomas Burkhardt and Dr. Delbert Mockma for being members on my guidance committee and whose valuable suggestions helped to shape this research topic.

I would like to thank Dr. Allan L. Phillips for coordinating the collaboration of various government agencies for the collection of data in Puerto Rico and for being the outside examiner on my thesis oral examination.

In addition, I would like to express my gratitude to the University of Puerto Rico for support me during the period of this research.

Thanks to Phil Gerrish, Neba Ambe, and Misael Miranda for their help and valuable advises.

TABLE OF CONTENTS

LIST OF TABLES.....	ix
LIST OF FIGURES.....	xiv
I. INTRODUCTION.....	1
A. Overview of Puerto Rico	2
B. The South Coast of Puerto Rico.....	4
C. Agricultural overview of Puerto Rico.....	11
1. Land Authority and its relevance to agriculture.....	11
2. Facts of Puerto Rico's agriculture.....	11
3. Agricultural machinery in Puerto Rico.....	14
D. Probabilities of Working Days Used to Improve Agricultural Machinery Management.....	16
E. Objectives.....	17
II. LITERATURE REVIEW.....	19
A. Vegetable Production Situation in Puerto Rico.....	19
1. Economic situation.....	19
2. Vegetable production in the south coast.....	20
B. Sugar Production Situation in Puerto Rico.....	23
1. Economic situation.....	23
2. Sugarcane production in the south coast.....	24
3. Sugarcane field production.....	24
4. Sugarcane harvesting.....	26
C. Agricultural Mechanization in Puerto Rico.....	27

1. Tractors: type and quantity.....	28
2. Agricultural machinery research.....	29
D. Importance of PWD in the Selection of Agricultural Machinery.....	31
E. Simulation Model Uses in the Analysis of Agricultural System.....	35
F. Prediction of PWD Using Soil Moisture Content Budget From Available Weather Data.....	38
1. Previous works.....	39
2. Soil consistency used to determine a suitable day for field operations.....	42
3. Soil moisture content budget.....	45
4. Definition of a tractable and a workable day.....	54
III. METHODOLOGY.....	57
A. Research Approach.....	57
B. Theoretical Approach.....	61
1. Development of the models.....	62
a. Crop root zone assumptions.....	67
b. Modified Hunt (1986) model.....	67
c. Modified Tulu et al. (1974) model.....	82
d. Modified Babeir et al. (1986) model.....	94
2. Validation of Models.....	104
a. Soil characteristics.....	104
b. Computation of soil moisture depth.....	105
c. Soil moisture sampling.....	106
d. Field operations experimental areas.....	110
e. Field operations observed data collection.....	122
f. Models validation process.....	129

3. Sensitivity analysis of the models.....	130
4. PWD tables computation.....	131
IV. RESULTS AND DISCUSSION.....	132
A. Validation of Models.....	133
1. Observed data evaluation.....	135
2. Missed weather data and its effect in the validation of the models.....	136
3. Modified Hunt (1986) model validation.....	137
4. Modified Tulu et al. (1974) model validation.....	156
5. Modified Babeir et al. (1986) model validation.....	175
B. Sensitivity Analysis.....	194
1. Modified Hunt (1986) model sensitivity analysis.....	194
2. Modified Tulu et al. (1974) model sensitivity analysis.....	198
3. Modified Babeir et al. (1986) sensitivity analysis.....	204
C. Soil moisture measurements.....	210
D. Comparisons of measured and predicted soil moisture content by the models.....	215
E. Selection of a PWD model and PWD tables results.....	220
V. CONCLUSIONS.....	227
VI. RECOMMENDATIONS.....	229
VII. REFERENCES.....	230
APPENDIX A: Input data and output files examples.....	238
APPENDIX B: Computer programs.....	257
APPENDIX C: Examples of documents used to collect field operations observed data.....	297
APPENDIX D: Field operations rough data.....	302

APPENDIX E: Soil moisture samples data.....	361
---	-----

LIST OF TABLES

Table	Page
1. Mean, maximum, and minimum temperatures for three weather stations located in the south coast of Puerto Rico.....	7
2. Monthly rainfall and class A pan evaporation for two agricultural experiment substations in the south coast of Puerto Rico.....	8
3. Population densities of selected American countries.....	13
4. Area used by the South Coast Vegetables Program for production of the most important vegetables in Santa Isabel Valley.....	22
5. Area used by the South Coast Vegetables Program for production of the most important vegetables in Guanica Valley.....	22
6. Sugarcane area harvested on different regions of Puerto Rico during the period of 1988-90.....	25
7. Sugarcane area harvested using combines on different regions of Puerto Rico during the period of 1988-90.....	25
8. Example of a PWD table.....	34
9. Selected locations according to crop type and field operations.....	60
10. Soil parameters for selected soils in the South Coast of Puerto Rico.....	106
11. Soil parameters used by each modified model for all the locations.....	111
12. Monthly crop coefficients (Kc) used on each location.....	115

13.	Modified Hunt (1986) model validation results predicting tillage operations.....	138
14.	Modified Hunt (1986) model validation results predicting non-tillage operations.....	139
15.	Results in the prediction of working days and output agreement for tillage operations at the Santa Isabel Valley vegetable field locations using modified Hunt (1986) model.....	144
16.	Results in the prediction of working days and output agreement for non-tillage operations at the Santa Isabel Valley vegetable field locations using modified Hunt (1986) model.....	146
17.	Results in the prediction of working days and output agreement for tillage operations at the Santa Isabel Valley tomato field locations using modified Hunt (1986) model.....	148
18.	Results in the prediction of working days and output agreement for non-tillage operations at the Santa Isabel Valley tomato field locations using modified Hunt (1986) model.....	149
19.	Results in the prediction of working days and output agreement for tillage operations at the Guanica Valley vegetable field locations using modified Hunt (1986) model.....	151
20.	Results in the prediction of working days and output agreement for non-tillage operations at the Guanica Valley vegetable field locations using modified Hunt (1986) model.....	153
21.	Results in the prediction of working days and output agreement for tillage operations performed by crawler tractors at Guanica Valley vegetable field locations using modified Hunt (1986) model.....	155
22.	Modified Tulu et al. (1974) model validation results predicting tillage operations.....	157
23.	Modified Tulu et al. (1974) model validation results predicting non-tillage operations.....	158
24.	Results in the prediction of working days and output agreement for tillage operations at the Santa Isabel Valley vegetable field locations using modified Tulu et al. (1974) model.....	163

36.	Results in the prediction of working days and output agreement for non-tillage operations at the Santa Isabel Valley tomato field locations using modified Babeir et al. (1986) model.....	187
37.	Results in the prediction of working days and output agreement for tillage operations at the Guanica Valley vegetable field locations using modified Babeir et al. (1986) model.....	189
38.	Results in the prediction of working days and output agreement for non-tillage operations at the Guanica Valley vegetable field locations using modified Babeir et al. (1986) model.....	191
39.	Results in the prediction of working days and output agreement for tillage operations performed by crawler tractors at Guanica Valley vegetable field locations using modified Babeir et al. (1986) model.....	193
40.	Sensitivity analysis results for modified Hunt (1986) model testing working day operation criteria in the computation of working days for the Santa Isabel Valley tomato field locations.....	195
41.	Sensitivity analysis results for modified Hunt (1986) model testing soil parameters.....	197
42.	Sensitivity analysis results for modified Tulu et al. (1974) model testing working day operation criteria in the computation of working days for the Santa Isabel Valley tomato fields location.....	199
43.	Sensitivity analysis results for modified Tulu et al. (1974) model testing soil parameters.....	201
44.	Sensitivity analysis results for modified Babeir et al. (1986) model testing working day operation criteria in the computation of working days for the Santa Isabel Valley tomato fields location.....	206
45.	Sensitivity analysis results for modified Babeir et al. (1986) model testing soil parameters.....	208
46.	Probability of working days (PWD) for field operations at Santa Isabel Valley vegetable location.....	222

47.	Probability of working days (PWD) for field operations at Santa Isabel Valley tomato location.....	223
48.	Probability of working days (PWD) for field operations at Guanica Valley vegetable location.....	224
49.	Probability of working days (PWD) for tillage operations performed with crawler tractors at Guanica Valley vegetable location.....	225
50.	Hypothesized probability of working days (PWD) for sugarcane harvesting operations at the Santa Isabel Valley location.....	226
D.1.	Observed tillage operations data and definition of working days for the Santa Isabel Valley vegetable field locations.....	303
D.2.	Observed non-tillage operations data and definition of working days for the Santa Isabel Valley vegetable field locations.....	311
D.3.	Observed tillage operations data and definition of working days for the Guanica Valley vegetable field locations.....	322
D.4.	Observed non-tillage operations data and definition of working days for the Guanica Valley vegetable field locations.....	330
D.5.	Observed tillage operations data and definition of working days for the Santa Isabel Valley tomato field locations.....	340
D.6.	Observed non-tillage operations data and definition of working days for the Santa Isabel Valley tomato field locations.....	344
D.7.	Observed tillage operations performed with crawler tractors data and definition of working days for the Guanica Valley vegetable field locations.....	355
E.1.	Soil moisture content (SMC) samples for San Anton silty clay seeded with pumpkins.....	362
E.2.	Soil moisture content (SMC) samples for Santa Isabel clay with plastic mulch and no crop.....	363
E.3.	Soil moisture content (SMC) samples for Santa Isabel clay in bare condition.....	364

LIST OF FIGURES

Figure	Page
1. Location of Puerto Rico in the Caribbean Sea.....	3
2. Climatic regions of Puerto Rico.....	5
3. Monthly Class A pan evaporation and rainfall for the Fortuna Agric. Exp. Substation located in the south coast of Puerto Rico.....	9
4. Monthly Class A pan evaporation and rainfall for the Lajas Agric. Exp. Substation located in the southwestern coast of Puerto Rico.....	9
5. Location of the most important agricultural valleys in the south coast of Puerto Rico.....	10
6. Atterberg consistency limits and their relation with field machinery operations.....	44
7. Example of a soil moisture-characteristic curve.....	48
8. Conceptual model for the computation of PWD.....	63
9. General flow chart for the computation of PWD.....	64
10. Conceptual model of the soil moisture content and plant relationship for Hunt (1986) model modified for this thesis.....	69
11. Flow chart of the soil moisture balance for the prediction of PWD based on Hunt (1986) modified model.....	70
12. Comparison of PET calculated with the Class A pan evaporation method and Hargreaves and Samani (1985) method for the Fortuna Agriculture Experimental Station during the period of June 1989 to December 1990.....	73
13. Conceptual model of the soil moisture content and plant relationship for Tulu et al. (1974) model modified for this thesis.....	85

14.	Flow chart of the soil moisture balance for the prediction of PWD for Tulu et al. (1974) modified model.....	86
15.	Conceptual model of the soil moisture content and plant relationship for Babeir et al. (1986) model modified for this thesis.....	96
16.	Flow chart of the soil moisture balance for the prediction of PWD for Babeir et al. (1986) modified model.....	97
17.	Santa Isabel Valley vegetable fields location.....	113
18.	Santa Isabel Valley tomato fields location.....	117
19.	Guanica Valley vegetable fields location.....	119
20.	Guanica Valley tillage operations performed with crawler tractors on vegetable fields location.....	121
21.	Santa Isabel Valley sugarcane harvesting operations performed with combines locations.....	123
22.	Comparison of the observed and predicted working for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Hunt (1986) model.....	140
23.	Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Santa Isabel Valley location using modified Hunt (1986) model.....	140
24.	Comparison of the observed and predicted working for tillage operations on tomato fields at the Santa Isabel Valley location using modified Hunt (1986) model.....	141
25.	Comparison of the observed and predicted working for non-tillage operations on tomato fields at the Santa Isabel Valley location using modified Hunt (1986) model.....	141
26.	Comparison of the observed and predicted working for tillage operations on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.....	142

27.	Comparison of the observed and predicted working for non-tillage operations on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.....	142
28.	Comparison of the observed and predicted working for tillage operations performed with crawler tractors on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.....	143
29.	Comparison of the observed and predicted working for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.....	159
30.	Comparison of the observed and predicted working for non-tillage operations on vegetable fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.....	159
31.	Comparison of the observed and predicted working for tillage operations on tomato fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.....	160
32.	Comparison of the observed and predicted working for non-tillage operations on tomato fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.....	160
33.	Comparison of the observed and predicted working for tillage operations on vegetable fields at Guanica Valley location using modified Tulu et al. (1974) model.....	161
34.	Comparison of the observed and predicted working for non-tillage operations on vegetable fields at the Guanica Valley location using modified Tulu et al. (1974) model.....	161
35.	Comparison of the observed and predicted working for tillage operations performed with crawler tractors on vegetable fields at the Guanica Valley location using modified Tulu et al. (1974) model.....	162
36.	Comparison of the observed and predicted working for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Babeir et al. (1986) model.....	178

47.	Comparison of measured soil moisture content (SMC) on the Santa Isabel clay soil with plastic mulch and no crop treatment with the modified model outputs.....	218
48.	Comparison of measured soil moisture content (SMC) on the Santa Isabel clay soil with in bare condition treatment with the modified model outputs.....	219
C.1.	Example of the "Informe de Servicio de Maquinaria Agricola" - South Coast Vegetable Program.....	299
C.2.	Example of the "Resumen de uso de horas de operadores" - Agricultural Services Administration.....	301

I. INTRODUCTION

The effective use of machinery in world food and fiber production, including vegetables and sugar, is well established. In countries where farm labor costs are high and agriculture is strongly dependent on farm machinery, the selection and sizing of agricultural machinery can significantly affect the success of agricultural enterprises. In the United States, livestock farm machinery expenses are approximately 30%, a significant portion of the total farm production costs (Lee et al., 1988). Farm machinery operations such as planting, tillage, and harvesting, are dynamically interrelated. Any change to a single machinery operation can interact and affect the overall farm performance. Delays in tillage operations, for example, can subsequently delay planting and harvesting. Such delays can significantly affect crop yields and farm profit.

Probabilities of working days (PWD) have been used world wide as a tool to assist in the selection of farm machinery (Tulu et al., 1974; Hetz, 1983). PWD values for the south coast of Puerto Rico are not available.

A. Overview of Puerto Rico.

Puerto Rico is a tropical island in the Caribbean Sea. It is part of the curved chain of islands called West Indies which incorporates the Bahamas, and the Greater and Lesser Antilles. Puerto Rico is the smallest island of the Greater Antilles. The country is located on the latitude 18° N and longitude 66° W and measures about 160 kilometers from east to west, and 56 kilometers from north to south (See Figure 1). About 40% of the island can be described as mountainous, 35% as hilly, and 25% as plains (Pico, 1974). The hills and mountains are concentrated in the central mountain chain called the Cordillera Central. More than 50% of the island exceeds an elevation of 150 m (500 ft) above sea level with the highest point at 1240 m (4300 ft). Slopes of 50% or more are common.

Using the Soil Conservation Service (SCS) productivity classification of the island soils, ranking from 1 to 10 in which 1 denotes the most productive and 10 the least, only 6 per cent are ranked as number 1. The most productive soils are located principally along the south coast (Pico, 1974). These soils are the most fertile of the island due to low erosion and low leaching of nutrients; also an annual deposit of sediments is washed down from the limestone and volcanic uplands during the rainy season (Gierbolini, 1979).

The soils classified from 1 to 5 cover 28 per cent of the island's total area. The remaining 72 per cent are

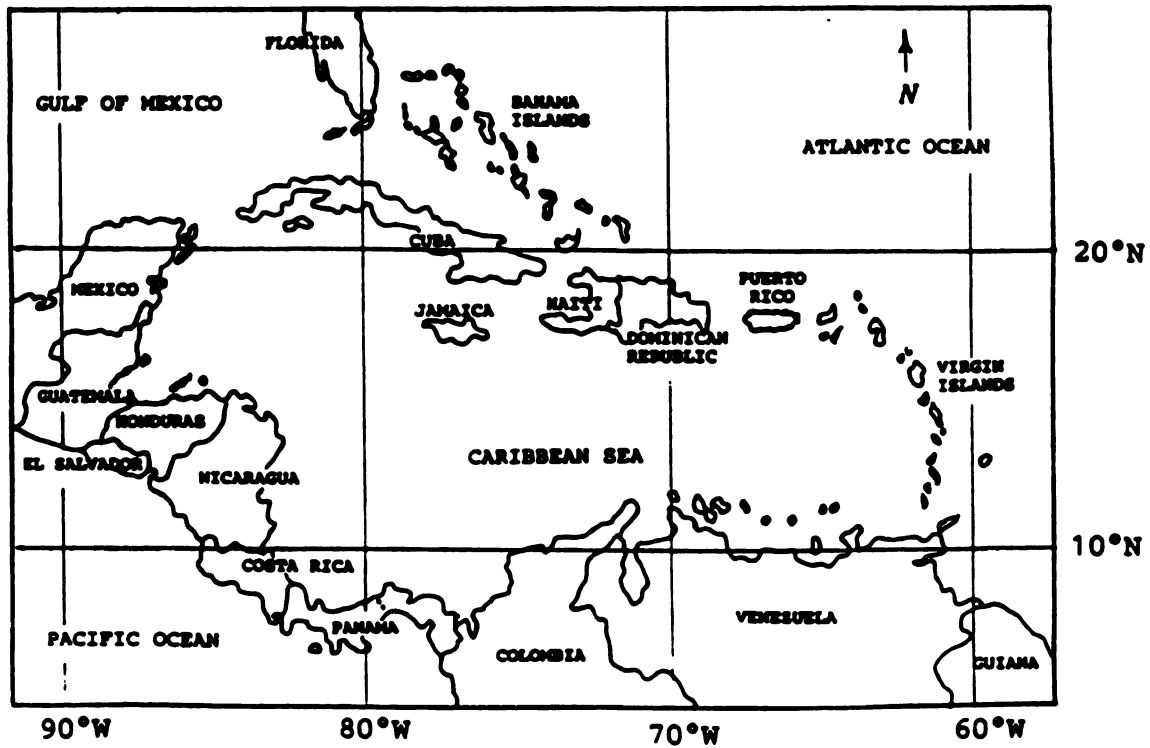


Figure 1. Location of Puerto Rico in the Caribbean Sea.

classified from 6 to 10. In other words, almost three quarters of the island is covered by low productive soils (Pico, 1974).

The weather of Puerto Rico is classified as tropical. Temperature changes are small, and the seasons are not really defined (Capiel and Calvesbert, 1976). The maximum and minimum annual temperatures are 30 °C (86 °F) and 19.3 °C (66.9 °F) respectively with an average temperature of 24.7 °C (76.5 °F).

The island is divided into climatic regions (See Figure 2). The annual rainfall in the northern, east-central, northeastern, and northwest-interior regions ranges from 150 to 200 cm along the immediate coast to over 200 cm near foothills. The heaviest rainfall of 225 cm or more occurs east and southeast of Luquillo mountains.

Precipitation distribution during the year, unlike temperature is highly variable. Two seasons are observed, dry and rainy. In general, the dry season begins in December and ends in September giving way to the rainy season.

B. The South Coast of Puerto Rico

This climatic region extends from east to west along the south coast; it is located between the towns of Arroyo and Cabo Rojo. Ponce is the main city in the region.

The south coast of Puerto Rico has a semi-arid climate.

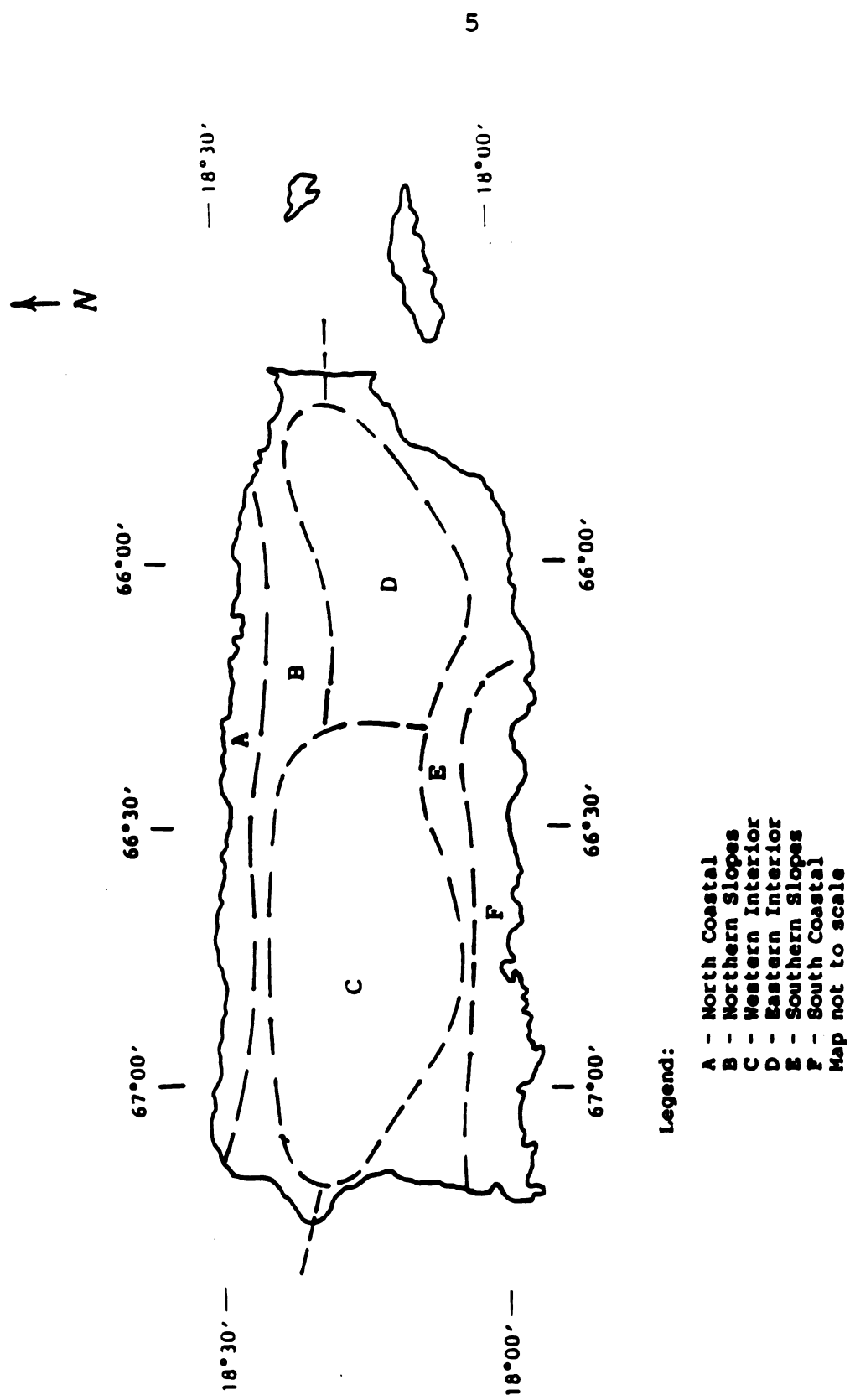


Figure 2. Climatic regions of Puerto Rico.

A semi-arid climate is defined as "a climate neither entirely arid nor strictly humid, but intermediate, with a shading to the arid state" (Farrall and Albrecht, 1965). The annual mean temperature is 25.8 °C (78.4 °F). Annual maximum and minimum temperatures are 31.2 °C (88.2 °F) and 20.5 °C (68.9 °F), respectively (See Table 1).

This region receives the least rainfall of the island, an average of 70 to 100 centimeters annually. An agricultural water balance approach in the south coast is critical. In general mean monthly rainfall is less than mean monthly potential evapotranspiration (See Figures 3 and 4). Deficit on rainfall generates drought conditions. Commonly, seven months average less than 10 cm of rainfall during the year. Rainfall deficiency becomes more critical in June and July since higher temperatures and longer days cause draught conditions (Capiel and Calvesbert, 1976).

The south coast has three important agricultural valleys: Santa Isabel, Guanica, and Lajas. The valleys are located along 18° N latitude and 66° 20' W, 66° 50' W, and 67° 00' W longitude respectively (Figure 5). The first two valleys have been used for vegetable production during the last decade by government agricultural programs. The third one (Lajas Valley) is used to produce vegetables but not under the government vegetable program. Sugarcane is cultivated in the entire region.

Table 1. Mean, maximum, and minimum temperatures for three weather stations located in the south coast of Puerto Rico. (Goyal and Gonzalez, 1989a)

Month	Temperature (°C)										
	Lajas Substation			Ponce 4E			Aguirre Central			South Coast	
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Mean
Jan	30.0	16.2	23.1	29.7	18.4	24.1	29.9	20.0	25.0	24.0	24.0
Feb	30.1	16.3	23.2	29.9	18.6	24.2	29.8	19.9	24.9	24.1	24.1
Mar	30.7	16.8	23.7	30.2	18.9	24.6	30.2	20.5	25.4	24.6	24.6
Apr	31.1	18.2	24.6	30.6	19.9	25.2	30.6	21.5	26.1	25.3	25.3
May	31.5	20.1	25.8	30.9	21.5	26.2	31.2	22.7	27.0	26.3	26.3
Jun	32.4	20.8	26.6	31.6	22.4	27.1	31.7	23.4	27.6	27.1	27.1
Jul	32.7	20.3	26.6	32.2	22.6	27.4	32.1	23.6	27.9	27.3	27.3
Aug	32.6	20.4	26.5	32.2	22.4	27.3	32.5	23.7	28.1	27.3	27.3
Sep	32.1	20.5	26.3	31.8	22.1	26.9	32.5	23.2	27.9	27.0	27.0
Oct	31.3	20.1	25.7	31.4	21.8	26.7	32.3	22.9	27.6	26.7	26.7
Nov	31.1	18.9	24.9	30.7	20.5	25.6	31.7	22.1	26.9	25.8	25.8
Dec	30.3	17.1	23.7	30.1	18.9	24.5	30.7	21.0	25.9	24.7	24.7
Annual Mean	31.3	18.8	25.1	31.0	20.7	25.8	31.3	22.0	26.7	25.8	25.8

Table 2. Monthly rainfall and Class A Pan evaporation for two agricultural experiment substations in the south coast of Puerto Rico (Goyal and Gonzalez, 1989a).

Month	Lajas Substation		Fortuna Substation	
	Rainfall	Evaporation	Rainfall	Evaporation
(mm)				
Jan	48.1	115.7	23.8	153.2
Feb	37.0	129.7	20.3	158.5
Mar	44.1	172.2	32.6	197.1
Apr	76.1	179.2	53.5	206.0
May	100.2	185.9	105.0	195.7
Jun	60.4	187.5	59.3	201.9
Jul	89.7	186.4	62.7	215.8
Aug	137.9	167.2	110.1	211.1
Sep	172.4	142.6	127.0	175.2
Oct	146.6	127.3	168.6	158.0
Nov	126.7	108.2	115.8	135.9
Dec	70.8	100.7	38.3	140.9
Annual Mean	92.5	150.2	76.4	179.1

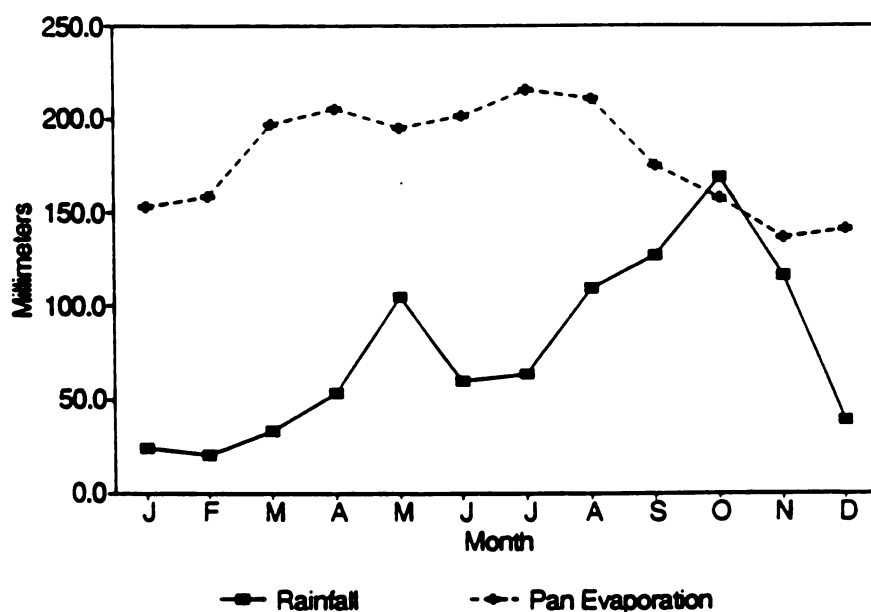


Figure 3. Monthly Class A Pan evaporation and rainfall for the Fortuna Agric. Exp. Substation located in the south coast of Puerto Rico.

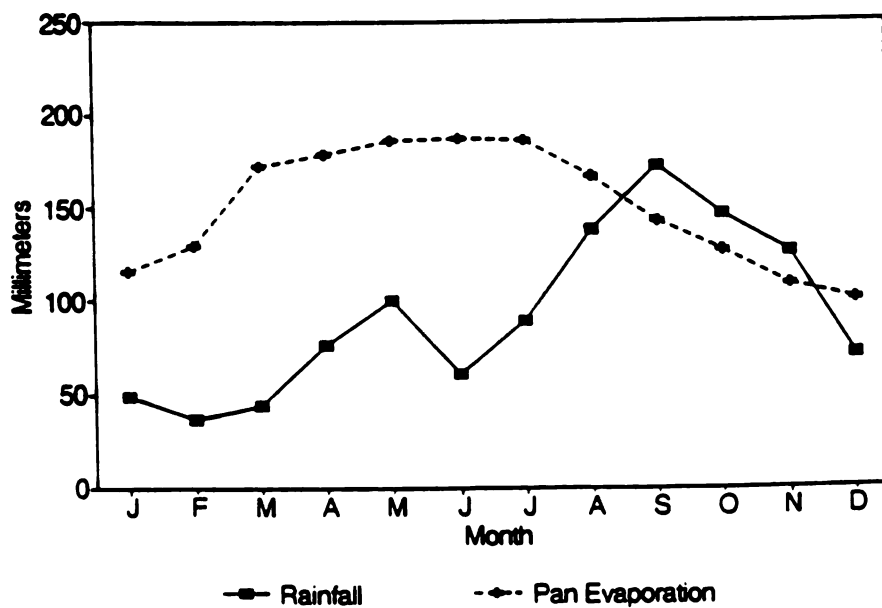


Figure 4. Monthly Class A Pan evaporation and rainfall for the Lajas Agric. Exp. Substation located in the Southwestern coast of Puerto Rico.

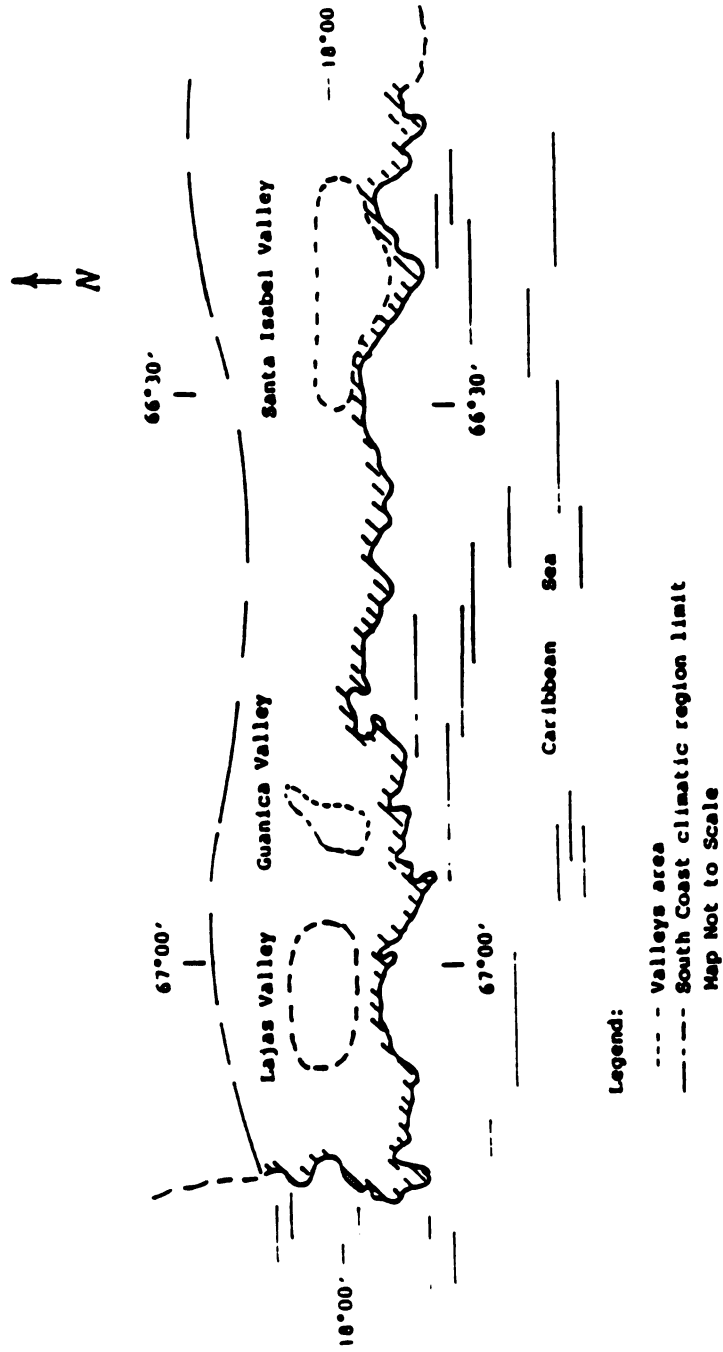


Figure 5. Location of the most important agricultural valleys in the south coast of Puerto Rico.

C. Agricultural Overview of Puerto Rico.

The following section contains a description of the Land Authority and facts of Puerto Rico's agriculture. Since its creation, the Land Authority has had a great impact on Puerto Rican agriculture.

1. Land Authority and its relevance to agriculture.

In 1944, Act No. 26, known as "Land Law", authorized the reorganization of land tenure in the island. Its objective was the acquisition and redistribution of land held in excess of 200 ha (500 acres) by corporations, societies, and other juridical organizations. This acquired land is accessible to farmers and others interested in agricultural projects.

The Sugar Corporation is a subsidiary of the Land Authority. This corporation is in charge of the sugar production in the island. There are other operational programs in the Land Authority: the Vegetable Program, the Pineapple Program, the Department of Real State, and the Conservation of Flooded Lands.

2. Facts of Puerto Rico's agriculture.

A 12 month growing season permits the production of crops throughout the year where enough rainfall or

irrigation water is available. Most of the agricultural projects in Puerto Rico are highly subsidized by several government programs. Puerto Rico has one of the highest population densities in Latin America and in the world (See Table 3), as such, it has less land in cultivation and thus imports most of its food. For these reasons, it is imperative to maximize productivity and preserve farm land through improved soil management practices.

The use of large agricultural machines, especially for tillage operations, is one of many factors that affects productivity and also decreases soil conservation. The necessity to adopt the use of new and efficient technology for agricultural development has become urgent. Good management practices and better use of machinery during farm operations will reduce the risk of land degradation, increase the efficiency of the machinery, increase crop yields, and reduce operation costs (Agr. Exp. Sta U.P.R., 1983). Sugarcane and vegetable production require intensive use of machines for most of the field operations, especially tillage. In Puerto Rico, the production of vegetables involves a technology which makes use of manual and mechanical power as complementary inputs for most farm operations: weeding, harvesting, plastic mulch layout, etc. These operations require 50% of the total man-hr per ha. Tillage operations require only 0.3% of the total man-hr per ha (Goyal, 1983). Unfortunately, from the soil management standpoint, the growing season of most of the vegetables

Table 3. Population densities of selected American countries (Collier's encyclopedia, 1992).

<u>Country</u>	<u>Area</u>	<u>Population</u>	<u>Year</u>	<u>Population Density</u>
	(km ²)	(peoples)		(peoples/km ²)
Argentina	2,780,092	32,700,000	1991	12
Brazil	8,511,965	153,000,000	1991	18
Chile	756,625	13,400,000	1991	18
Colombia	1,141,748	32,450,000	1991	28
Costa Rica	51,100	2,733,000	1987	53
Cuba	110,861	10,036,000	1985	91
Dominican Republic	48,442	7,320,000	1991	151
Guatemala	108,475	8,895,000	1987	82
Honduras	112,088	5,300,000	1991	47
Jamaica	10,991	2,446,000	1988	222
Mexico	1,972,547	90,000,000	1991	46
Panama	77,082	2,733,000	1991	35
Puerto Rico	9,104	3,196,520	1980	358
Venezuela	912,050	19,735,000	1990	22
USA	9,372,570	253,000,000	1992	27

coincides with the rainy season.

Various problems have been found in the sugar industry; low sugar yield per hectare and high production cost are some of the examples of these problems. Low yields have generally been attributed to the inadequate use of modern techniques, inadequate farm location, and the loss due to poor shipping and handling (Troche, 1987).

To avoid land degradation caused by excessive use of machinery in wet soils, farmers and government agencies need a tool such as a "probability of working days" (PWD) to assist them in setting the best work schedule for farm machinery operations for the area.

3. Agricultural Machinery in Puerto Rico.

Puerto Rico depends on importation for tractors and other agricultural implements. The USA is the source of a large fraction of all the imported agricultural machinery. In recent years Puerto Rico's agriculture has been mechanized to a high degree especially for vegetable and sugarcane production. In general, farmers of the coast, where the soil conditions allow farm mechanization, own their machinery. In most of the cases tractors and implements are modified to adapt to the particular environment.

The government of the island has various machinery service programs to help the farmers in the proper mechanization of their agricultural lands. Some of these programs

help specific production sectors while other serve all farmers. The programs are:

1. Sugarcane Corporation of the Land Authority This program was developed to serve the farmers of the sugarcane production. It is distributed over the entire island.
2. Pineapple Program of the Land Authority This program is located in the north part of the island and assists pineapple producers.
3. Agricultural Services Administration (ASA) This program is part of the Department of Agriculture and was created to serve all farmers. Its services include: land preparation, maintenance of farm roads, land leveling, pond construction, and others. Machinery on this program is mainly crawler tractors and heavy duty tillage implements. Its services are located island wide.
4. Vegetable Programs of the Land Authority Machinery in this program is destined to serve farmers associated with the Vegetable Program located in the south coast. The program covers two main areas in the region: Santa Isabel Valley and Guanica Valley. Details of this program are discussed in the literature review.

**D. Probabilities of Working Days Used to Improve
Agricultural Machinery Management.**

Among the major economic decisions made by farmers producing row crops and sugarcane include selection of tractors and implements. Agricultural machinery and equipment expenses represent one of the major categories of costs in crop production (Boehlje and Eidman, 1984). The share of total crop production cost in the corn belt States due to machinery is exceeded only by land cost (Ozkan and Edwards, 1986).

Year to year variation in weather and its resultant impact on the number of good days available for soil preparation, planting, spraying, cultivation and harvesting has been a major uncertainty in making good machinery selections. PWD is a method developed by scientists and farmers to determine the number of working days available to perform a specific field machinery operation in a given time period. PWD is a function of: climatic region, slope of soil surface, soil type, drainage characteristics, operation to be performed, and traction and flotation devices (ASAE, 1984).

Freezing temperatures, precipitation, excessive and deficient soil moisture, and other weather related factors may limit field machinery operations. As weather variability is great and the natural occurrences of its events are considered to vary randomly, any prediction of

the number of future working days can only be made probabilistically (ASAE, 1984).

The literature reports two categories of working day data generation: 1) observed data for a location and year (Link, 1968; Fulton et al., 1976), and 2) generated data using simulation models based on weather and soil parameter inputs (Tulu et al., 1974; Hunt, 1986; Babeir et al., 1986). Relatively few detailed records have been kept on field working conditions by farmers and government agencies. No observed working day records are available for vegetable production and sugarcane harvesting on the south coast of Puerto Rico.

E. Objectives.

The overall goal of this research is to improve economic returns to Puertorican farmers through the optimum utilization of machinery resources. This will be done by developing the probabilities of working days (PWD) tables for the south coast of Puerto Rico.

The specific objectives of this research are to:

1. Test three models in the prediction of expected working days for different regions and crops of the south coast of Puerto Rico.
2. Select the best method for the estimation of

probabilities of working days for the south coast of Puerto Rico.

3. Develop probabilities of working days (PWD) tables, at different levels of probability, from available weather data for the south coast of Puerto Rico.

II. LITERATURE REVIEW

A good machinery management program requires the best utilization of its resources. Farmers all over the world know that agriculture should be operated as any other important business. For that reason, care must be taken as the selection of machinery may directly affect the most important agricultural resources: soil and water. In this section PWD is discussed, emphasizing its utility in Puerto Rico's agriculture.

A. Vegetable Production Situation in Puerto Rico.

1. Economic situation.

Puerto Rico's climate and resources are suited to a wide variety of vegetable production. Several crops may be obtained from the same field each year, for different markets. Tomatoes and other vegetables can be exported to the United States during winter time when Florida and other states can not produce them. As such, the government of Puerto Rico in 1985 developed a vegetable production program to produce high quality vegetables, to reduce the importation of vegetables to the island, and to increase the

market of vegetable during the off-season of vegetables in the US.

2. Vegetable production in the south coast.

The semiarid south coast of Puerto Rico consists of more than 27,524 hectares of agricultural land with favorable conditions and potential for vegetable production (Rivera, 1986). This zone, the Island's driest zone, has fertile soils highly recommended for intensive vegetable production if an irrigation system is used.

During the past several years a great effort by the government to increase vegetable production has been observed continuously. Since the creation of the South Coast Vegetable Program (SCVP) by the Land Authority Act 10 in May 1985, the south coast has been converted into an important branch of Puerto Rico's economy.

The land used by this program was originally devoted to the production of sugarcane. In the 70's sugarcane decreased its production, and this land was partially abandoned.

The SCVP is located in two valleys: Santa Isabel Valley and Guanica Valley, and covers more than 2,300 ha. Over 70 farmers are participants in the program, which uses advanced technology to produce more than 20 types of vegetables. The program services include land leasing, agricultural machinery and tractors service, technical consultation, weed and pest control, and receiving,

classification, packing and marketing of products. In addition, greenhouses for seed production, pollinator bees, etc. are also made available to farmers to increase production yields (Land Authority, 1990).

About 2,000 hectares of production land are drip irrigated. The most important crops during the last years in the region were tomatoes, peppers, pumpkins, melons, cucumbers, eggplants, and onions (See Tables 4 and 5).

The growing season for the most common vegetables starts in October and ends in April or May. Land preparation starts in July when the dry season is ending. Some vegetables need plastic mulch and layout of drip irrigation lines. These operations are accomplished during September (Santiago, 1992).

Other independent farmers are producing vegetables in the south coast region. Independent farmers are those that receive a minimum service from government programs and are not directly affiliated with the SCVP. In general they have their own machinery. Some of the services they receive from the SCVP are renting of harvesting carts, weed and pest control, and receiving, classification, packing and marketing.

Table 4. Area used by the South Coast Vegetables Program for production of the most important vegetables in Santa Isabel Valley (Alamo, 1990; 1991; 1992).

Crop	Area (ha)		
	1988-89	1989-90	1990-91
Tomatoes	247	233	221
Peppers	182	185	217
Pumpkins	355	217	139
Melons	*	174	128
Onions	85	54	74
Cucumbers	41	63	59
Eggplants	77	61	58
Total	986	988	896

* not reported this year

Table 5. Area used by the South Coast Vegetables Program for production of the most important vegetables in Guanica Valley (Alamo, 1990; 1991; 1992).

Crop	Area (ha)		
	1988-89	1989-90	1990-91
Pumpkins	71	74	58
Peppers	33	60	41
Onions	5	4	20
Tomatoes	7	9	1
Total	116	147	132

B. Sugar Production in Puerto Rico.

1. Economic situation.

During the past 30 years, the production of sugar in Puerto Rico has decreased dramatically due to the low price in the world market and high production costs. Puerto Rico as a commonwealth of the US has one of the highest farm wages in Latin America due to the federal minimum wage labor law. This makes it impossible for the country to compete in the free market with other countries where the cost of labor is lower.

In 1950 sugar production was 1.2 million tons. This number was reduced to 68,086 tons in 1990. The cultivated area for the same period decreased from 149,000 ha (369,000 acres) to 16,805 ha (41,525 acres) (Agr. Exp. Sta. UPR, 1983; Troche, 1991).

In view of the worsening situation for the sugar production it is necessary to implement the correct use of modern techniques of production, to obtain higher sugar production with lower production cost (Agr. Exp. Sta. UPR, 1983).

Inspite of its steady decline, the sugar industry remains an important sector in the economy of the country. Derivative products from this sector, principally molasses, are important raw materials for other industries of great importance, such as rum and livestock production (Troche,

1989)

The viability of using sugarcane tops and leaves as biomass fuels indicates that the sugarcane industry can improve its financial status by diversifying into the production of co-products, including electrical energy (Phillips, 1991).

2. Sugarcane production in the south coast.

The sugarcane harvested area along the south coast named Mercedita area, covered approximately 4100 ha (10,300 a) in 1990 (See Table 6). It is 23% of the island total production area. Mercedita area is divided in various important production regions: Santa Rita (Guanica Valley), Santa Isabel Valley, and Salinas town.

3. Sugarcane field production.

The Sugar Corporation is a public corporation of the Land Authority. Services from the Land Authority include rent of land, machinery services, pest control, and sugar mill processing factories.

Wide varieties of sugarcane have been used in Puerto Rico for sugar production depending on the planting season, soil, and climate. Some varieties are recommended for their

Table 6. Sugarcane area harvested on different regions of Puerto Rico during the period of 1988-90 (Troche, 1990; 1991; 1992).

Region	Area (ha)		
	1988	1989	1990
Aguirre	3770	3413	2524
Coloso	5276	4910	5032
Mercedita	5207	4408	4142
Plata	3601	3242	2860
Roig	2519	2588	2548
Total	20373	18561	17106

Table 7. Sugarcane area harvested using combines on different regions of Puerto Rico during the period of 1988-90 (Troche, 1990; 1991; 1992).

Region	Area (ha)		
	1988	1989	1990
Aguirre	2467	2288	1538
Coloso	2179	2135	2374
Mercedita	2337	1734	1862
Plata	622	461	550
Roig	2507	2499	2474
Total	10112	9117	8798

facility of harvest by combine. Traditionally, there are two sugarcane planting seasons in Puerto Rico spring planting from February to May to be harvested after 12 to 14 months, and fall planting from June to October to be harvested after from 16 to 18 months. Ratoons are harvested after 11 to 12 months.

4. Sugarcane harvesting.

Historically, the sugarcane harvest season begins in late January and ends in early May. This is mainly because the sugar content in the cane is at its maximum during this period, especially in March and April. In addition, the lack of rainfall during the dry season facilitates the harvesting process. Records from sugarcane factories regularly show that the highest average for the grinding season occurs in the later part of March and during April (Samuels et al., 1960).

The high sugar content has been attributed to the short photoperiod, the cold days, and the low rainfall that provokes the cessation of growth and the maturation of the cane (Capo, 1970). In general, cane with the same age harvested from July to December produced the highest cane yield with a lower sugar content compared with cane harvested from January to June. This fact is important because high tonnage might increase harvesting cost.

A harvesting plan is made considering the maturation

behavior of the varieties, age, soil moisture conditions, and vegetative development. The final goal of this harvesting plan is to harvest and quickly ship the cut cane fresh and with minimum extraneous materials (Barnes, 1974). Ideally all sugarcane should be harvested in its maximum maturation but in reality this is not achieved. The fraction harvested at maximum maturation depends on the sugar mill grinding capacity, the harvesting rate, and delays and irregularities in the movement of the cane from the fields to the mill.

C. Agricultural Mechanization In Puerto Rico.

Agricultural mechanization started at a low level in the twentieth century when United States capital was invested in the development of cane culture (Pico, 1974). Between 1940 and 1960 sugar cane production was partially mechanized. The mechanization of sugarcane harvesting in Puerto Rico was necessary because of a steadily decreasing availability of manual labor (Chisholm, 1976). Today, sugarcane harvest methods are about evenly divided between hand cutting and machine harvesting (See Table 7).

1. Tractors: type and quantity.

In 1924 and 1925 the number of tractors imported to the island from the US was 140 and 135, respectively (Dept. de

Agricultura y Trabajo, 1926). Shukla (1975) reported the degree of mechanization of the sugarcane industry between 1957 and 1973. The study included tractors from private farmers and government programs. He reported that the acquisition of wheel tractors was higher than that of crawler tractors at the end of the referred period. In 1961, one wheel tractor and 16 crawler tractors were acquired, while in 1972, 108 wheel and 26 crawler tractors were acquired. The average power of both types of tractors acquired during 1969 was about 100 hp compared with 50 hp in 1961.

Today combines utilized for harvesting in the south coast are mostly of the Claas¹ brand (Leon, 1992). These combines are provided by the Sugar Corporation Land Authority of Puerto Rico through a rental service. Usually the Sugar Corporation use 5 to 6 combines per day during each season in the Santa Isabel Valley. But the number may increase up to 8 in the last part of the harvesting season as the need arises (Land Authority, 1992). In sugar production the use of crawler tractors for land preparation is common.

During the period of 1989 to 1992 the SCVP counted with more than 70 tractors, mostly wheel type, which 66% included tractors with power between 80-90 hp. These are utilized to bring service to farmers on the program. Most of the

¹Trade names are used only for identification purposes and do not imply preferences for this harvesting machine by the author.

implements are modern and specialized. Additional sources of machinery services are the Agricultural Services Administration of the Department of Agriculture (ASA) as well as some private services in the area. ASA's tractors are mostly crawler type. They have been mainly used for tillage and land preparation due to their large size and power.

2. Agricultural machinery research.

No machinery selection research has been reported in Puerto Rico. A few agricultural machinery management research projects have been reported. Most of these works are related to yield responses of various vegetable crops, to tillage systems, or to land preparation techniques (Vicente-Chandler et al. 1966; Irrizarry and Rodriguez, 1984; Rivadeneira, 1982).

The results of tillage experiments conducted in Puerto Rico have been variable and highly dependent on soil conditions and crop. Lugo et al. (1987), for example, compared no-till (undisturbed), minimum-till (chisel plowing), conventional-till (disk plowing to 15 cm), and deep-till (disk plowing to 45 cm) preparation methods (in a Mollisol) for watermelon (var. Charleston Gray), tomato (var. Manulucie), and pigeon pea (var. 2B-Bushy) in the south coast region. They observed no significant effect on yield due to tillage method.

Other scientists have investigated the effect on crop yield of the soil moisture content (SMC) during land preparation. Merino (1977) found that a SMC between 20% and 22%, kg^{-1} , is best for tillage operations on Coto soil (clay) for soybean growth in the north coast of the island.

Lugo-Lopez and Acevedo (1956) reported that the use of heavy machinery in a clay soil in the south coast increases soil compaction and soil bulk density and reduces hydraulic conductivity. The result is an increased drainage period. Shukla (1974) conducted a soil compaction test in a Lajas Valley sugarcane field and found that the use of a single row soldier-type harvester machine did not severely compact the soil, whereas the loaded transport carts caused considerable soil compaction in the bank of the ridges.

During the seventies, a weekly report associated with weather and its effect on agriculture was published. "Clima y cosechas"² published by the Department of Agriculture of Puerto Rico (1972) in collaboration with the US Weather Bureau and Agricultural Extension Service of the University of Puerto Rico (UPR), reported weather conditions of the previous week and how crops and field operations were affected. It also included a weather forecast for the following week, a general SMC calculation for each region based on rainfall and evaporation data, expected SMC for the following week, and crop growing conditions. The

²Weather and Crops

publication was discontinued in 1978.

D. Importance of PWD in the Selection of Agricultural Machinery.

Selecting machine size involves assigning the proper size equipment to get a job done in a given period of time. Selecting the right equipment for a given farm size will increase profits. Machinery selection decisions require careful determination of machinery costs. These include fixed costs, operating costs, and timeliness costs. Timeliness is defined as the ability to perform an activity at such a time that the crop return is optimized, considering the quantity and quality of production (ASAE, 1984).

The effective field capacity (EFC) of a machine is an important factor to fit machine size to the amount of work which has to be completed in a specific length of time. EFC is the capacity of a machine as a function of its width and speed. This assumes the forward speed is the maximum speed not affecting operation or power (Hunt, 1983). EFC can be determined by the following equation:

$$EFC = \frac{S \times W \times E}{10} \quad [1]$$

where: EFC = effective field capacity, ha/h

S = operation speed, kph.

W = width of the machine, m

E = field efficiency, decimal

10 = constant to convert to hectares

Field efficiencies (E) for different operations and implements are estimated on the field for diverse field conditions. It is defined as the ratio of the theoretical productivity of a machine to its actual productivity (White, 1978). It takes into consideration the effective width of the machine, lost productivity time, and delays due to turnings at row ends or field corners, maneuvering around obstacles or obstructions, bad field conditions, waiting times, and other factors. Field efficiencies are also available from ASAE publications (ASAE, 1984) or other machinery management books or references (White, 1978; Hunt, 1983).

Because the number of suitable field working days varies from year to year, estimates of PWD at different probability levels are required. Fulton et al. (1976), suggested that for operations where failure to complete the work on time means only inconvenience or slight reductions of yield, a probability level of 0.50 might be acceptable. Such an operation might be applying fertilizer to pastures. Where timeliness is important for maximum yields, such as cereal seeding, a probability level of 0.70 is adequate. Where failure to complete an operation becomes costly due to

reduction of yields, such as cereal harvesting, a probability level of 0.80 or higher is desirable. Table 8 shows an hypothetical example of a PWD table for vegetable production with a growing season from October to April for the south coast of Puerto Rico. For tillage operations the farmers may expect working days to be a minimum of 100% (1.00) of calendar days for 50 years out of 100 during May or 88% (0.88) and 81% (0.81) for 75 years and 94 years out of 100 years, respectively, during the same period. This decimal number is the ratio of expected working days to total calendar days during the specified period. The dashes (--) in the first, second, and third columns of Table 8 represent months when tillage is not normally done. The dashes in the fourth, fifth, and sixth column represent the months when non-tillage operations are not normally done.

In order to select the best size (W) of a given machine to complete a farm operation knowing the field area and the available time for given location the following equations can be used:

$$EFC = \frac{A}{H \times D \times PWD} \quad [2]$$

where: A = land area covered by the machine in a season, ha

H = expected time available for field work each day, hr/day

Table 8. Example of a PWD table.

PROBABILITY OF WORKING DAYS FOR DIFFERENT FIELD OPERATIONS ON VEGETABLE PRODUCTION IN THE SOUTH COAST OF PUERTO RICO						
MONTH	TILLAGE			NON-TILLAGE		
	PROBABILITY LEVEL			PROBABILITY LEVEL		
	.50	.75	.94	.50	.75	.94
Jan	--	--	--	1.00	1.00	1.00
Feb	--	--	--	1.00	1.00	1.00
Mar	--	--	--	1.00	1.00	1.00
Apr	--	--	--	1.00	1.00	1.00
May	0.96	0.88	0.81	--	--	--
Jun	1.00	0.99	0.93	--	--	--
Jul	1.00	0.96	0.93	--	--	--
Aug	0.98	0.94	0.91	--	--	--
Sep	0.94	0.86	0.80	--	--	--
Oct	--	--	--	0.97	0.94	0.89
Nov	--	--	--	0.96	0.93	0.89
Dec	--	--	--	1.00	1.00	1.00

D = calendar days used for field work in a
season, days

PWD = probability of working days, decimal

Solving for W in equation 1 then provides:

$$W = \frac{EFC \times 10}{S \times E} \quad [3]$$

Field operations not completed on time will have a negative economic value: timeliness cost. These are not out-of-pocket costs but reductions in potential return, as

when yield and quality of a crop are reduced because of delays in harvesting. The equation used to compute timeliness cost (TC) in a machine operation (Hunt, 1983) is:

$$TC = \frac{K \times A^2 \times Y \times U}{SC \times H \times PWD \times EFC \times nt} \quad [4]$$

where: TC = timeliness cost, \$/year

K = timeliness loss factor for operation, decimal

Y = crop yield, unit/area

U = crop value, \$/unit

SC = schedule factor

SC = 2 for premature or delayed schedule

SC = 4 for balanced schedule

nt = number of times A should be divided for

multiple operations or varieties, no units

A, EFC, PWD, and H are previously defined

E. Simulation Model Uses in the Analysis of Agricultural System.

A system has been defined by Manetsh and Park (1977), as a collection of objects, called components, which interact synergistically to perform a given function or functions. The components are differentiated into: 1) exogenous or environmental variables; 2) endogenous or controllable input variables; 3) input parameters; and 4)

output variables. While recognizing the parts and the functions in the system the next step is to assemble and integrate the system's component parts in order to develop a more comprehensive conception of the system as a whole. It can be done by means of simulation models. System analysis is a term applied to the logical organization of data and theories concerning the behavior of various systems into models and the rigorous testing of such models for the purpose of validating and improving them. Finally the models can be used to predict the future behavior of the system which they represent (Hillel, 1977).

A simulation model can be defined as the construction of mathematical models to imitate the essential features and behavior of a real system (Hillel, 1977). Computers have been used in the simulation process because of the amount of data to be manipulated.

According to Smerage (1979) a model has two parts: 1) the conceptual model, and 2) the mathematical model. The conceptual model expresses the perceptions of its author about the components of the real system and their structural arrangement to form that system. It is usually expressed by schematic with supporting narrative. The mathematical model describes the properties of its behavior as a single entity. It consists of a set of equations for certain attributes of the components and the environmental stimuli.

The procedures for development of a simulation model according to Wright (1971) are:

- 1) Specification of the problem
- 2) Learn about the system
- 3) Formulation of the initial model
- 4) Data collection of the real system
- 5) Formulation of the detailed model
- 6) Programming
- 7) Validation and Verification
- 8) Experimentation
- 9) Analysis of results
- 10) Publication

All these steps are interrelated with each other. Feedbacks to any of the previous step are common in the development of a model. The data collection is the most difficult task to be accomplished and requires a great deal of time and effort (Hillel, 1977).

The process of evaluating the model in relation to the reality is referred as the validation and verification. Verification is concerned with the correct results in solving equations. A valid model is one which does what it is supposed to do. The model can be validated using statistical methods and simple regressions of the generated data as a functions of the actual data.

Experimentation with the model should be performed. Sensitivity analysis is used to test the model in the variation of one input at a time to look the impact on its output. Test of different combination of inputs and set of

inputs which provides optimum outputs are also recommended.

**F. Prediction of PWD Using Soil Moisture Content Budget
From Available Weather Data.**

Simulation models presented in this study (Tulu et al., 1974; Hunt, 1986; Babeir et al., 1986) are based on the premise that a suitable day for a given operation can be predicted if the soil moisture content (SMC) status in the first 150 mm layer of the soil profile is known. SMC is determined utilizing physical properties of the soil as well as weather data.

Thorntwaite (1954) pointed out the importance of climatic data in determining tractability: "Soil moisture is largely determined by precipitation which adds water and evapotranspiration which removes it. Since evapotranspiration is a function of temperature and length of the day, the basic factors of tractionability common to all soils are climatic". Hillel (1980) defined trafficability as the ability of the soil to provide traction and allow unobstructed overland passage of vehicles such as tractors, automobiles, tanks, etc. Tractability, tractionability, and trafficability are terms that have been used as synonymous. In this thesis the term tractability is utilized to identify working days for non-tillage operations.

Soil availability for tillage operations is expressed in terms of its workability conditions. Tractability and

workability terms will be discussed in section F.2.

1. Previous works.

In one of the earliest publications, Thornthwaite (1954) estimated the tractability of the soil for different regions in the US. This work was related with the movement of military equipment over the soil and was strictly strategic. Soil moisture computation was calculated for the first 60 cm (24 in) of soil profile. The use of the evapotranspiration formula developed by Thornthwaite (1948) was considered the most important parameter in the SMC computation. Another parameter considered by Thornthwaite was the estimation of rainfall intensity using daily rainfall and daily temperature data. Rainfall intensity was used to estimate water runoff and infiltration. Results were presented in form of climatic maps for selected areas of the US in a monthly bases.

In the literature reviewed by Thornthwaite (1954) a tractability study from the central Ural Region of the USSR was cited (Kachinski et al., 1950). They found that the plasticity of the soil influenced by the soil moisture content affected suitability of the soil for tillage operations. The optimum SMC for plowing plastic soils (loams, silts, clays) was suggested between 60 to 80 percent of field capacity (FC).

Shaw (1965) estimated field working days for spring in

Iowa. Soil moisture computation was determined for the first 15 cm of soil using weather data. In his method the evapotranspiration was assumed a constant daily loss of .25 cm/day (.1 in/day) because some evaporation data was not readily available. Cloudy conditions were also considered. Maximum available soil moisture for the top 15 cm of the profile was 22 mm (.9 in). The criterion used to define a working day was any day when the available soil moisture was less than 19 mm.

Rutledge and McHardy (1968) used a simplified version of the Versatile Budget developed by Baier and Robertson (1966) to predict tractability for Alberta, Canada. They defined the criteria for a tractability day as any day when the moisture content was 95 percent of the available water capacity (AWC).

Selirio and Brown (1972) reported PWD computations for spring cultivation in Ontario, Canada. The first 30 cm of the soil profile was divided into different layers. Results showed that cultivation was possible when the SMC was about 90 percent of the field capacity value to a depth of 12 cm (4.1 in), even when the SMC in the lower layers was higher.

Rosemberg et al. (1982) extended and refined the Tulu et al. (1974) model for Michigan. In this model, tractability was determined for six field operation categories. They validated the model with the correlation between predicted and farmer recorded "go", "no-go" day sequences on a monthly bases by two methods. These were (1) accuracy in

the day to day predictions and (2) the ability of the model to predict the number of field operation days based on time periods by examining bias of the model. Soil texture and drainage effect resulted the major impact in areas with the same weather conditions.

The DRAINMOD model developed by Skaggs (1978) has been used by Ozkan et al. (1990) to determine suitable field working days in the computation of machinery timeliness cost for corn production in Ohio. This model is based on a water balance in the soil profile computed on an hourly basis by calculating infiltration, drainage, subirrigation, and evapotranspiration. This model requires several inputs such as hourly precipitation, daily temperature, hydraulic conductivity of each soil horizon, soil water characteristics, drainage system parameters, soil tractability requirements, and crop parameters. DRAINMOD is limited to areas where the required input parameters are available or where these can be estimated confidently. The DRAINMOD model was not tested as a part of this thesis because many of the input parameters are not available for Puerto Rico.

The specifics of the Tulu et al. (1974), Hunt (1986) and Babeir et al. (1986) methods will be discussed in the methodology section.

2. Soil consistency used to determine a suitable day for field operations.

As was mentioned earlier there are several factors which determine the time available for field operations. Soil type, water holding capacity, and precipitation may directly affect the tractability or workability of the soil. The ability of the soil to resist field operations can be determined using the soil consistency properties.

Soil consistency was defined by Russell and Russell (1950) as cited by Hillel (1980):

"designates the manifestation of the physical forces of cohesion and adhesion acting within the soil at various moisture contents... to what extent can a body maintain its shape when subjected to forces tending to cause deformation as gravity, pressure, push, pull, tendency to adhere to foreign bodies".

The factor long recognized as the major determinant of soil consistency is the soil's degree of wetness, generally kg kg^{-1} . Also important are the percentage and type of clay in a soil. With respect to their response to moisture and therefore to tractability or workability, soils can be divided into two main groups, plastic (or cohesive) and non plastic (or cohesionless) (Thorntwaite, 1954).

Atterberg (1911, 1912) cited by Hillel (1980) devised simple empirical criteria to define the degree of wetness and soil consistency states called the "Atterberg limits". Soil consistency states are solid, semisolid, plastic, semiliquid, and liquid. The Atterberg limits are delineated

using the following constants: shrinkage, lower plastic (or plastic) limit, upper plastic (or liquid) limit, and flocculation limit (See Figure 6). From this point plastic and liquid limits will be used.

A useful index derived from the consistency limits is plasticity index (PI). This is defined as the difference of the SMC between the liquid limit (LL) and plastic limits (PL):

$$PI = LL - PL \quad [5]$$

where: PI = plasticity index SMC, kg kg^{-1}

LL = SMC at the liquid limit, kg kg^{-1}

PL = SMC at the plastic limit, kg kg^{-1}

A soil is considered tractable if a tractor and a non-tillage implement can move on that soil to perform their function without damaging the soil structure (Babeir et al., 1986). If excessive wheel slippage can reduce a tractor's effective pulling or cause serious soil structure damage, then the soil is considered unsuitable to be tracked (untractable). The maximum allowable SMC for non-tillage operation is near or below the liquid limit.

The soil is considered workable or suitable for tillage operations if the moisture content is near or below the plastic limit and above the shrinkage limit. If the soil is

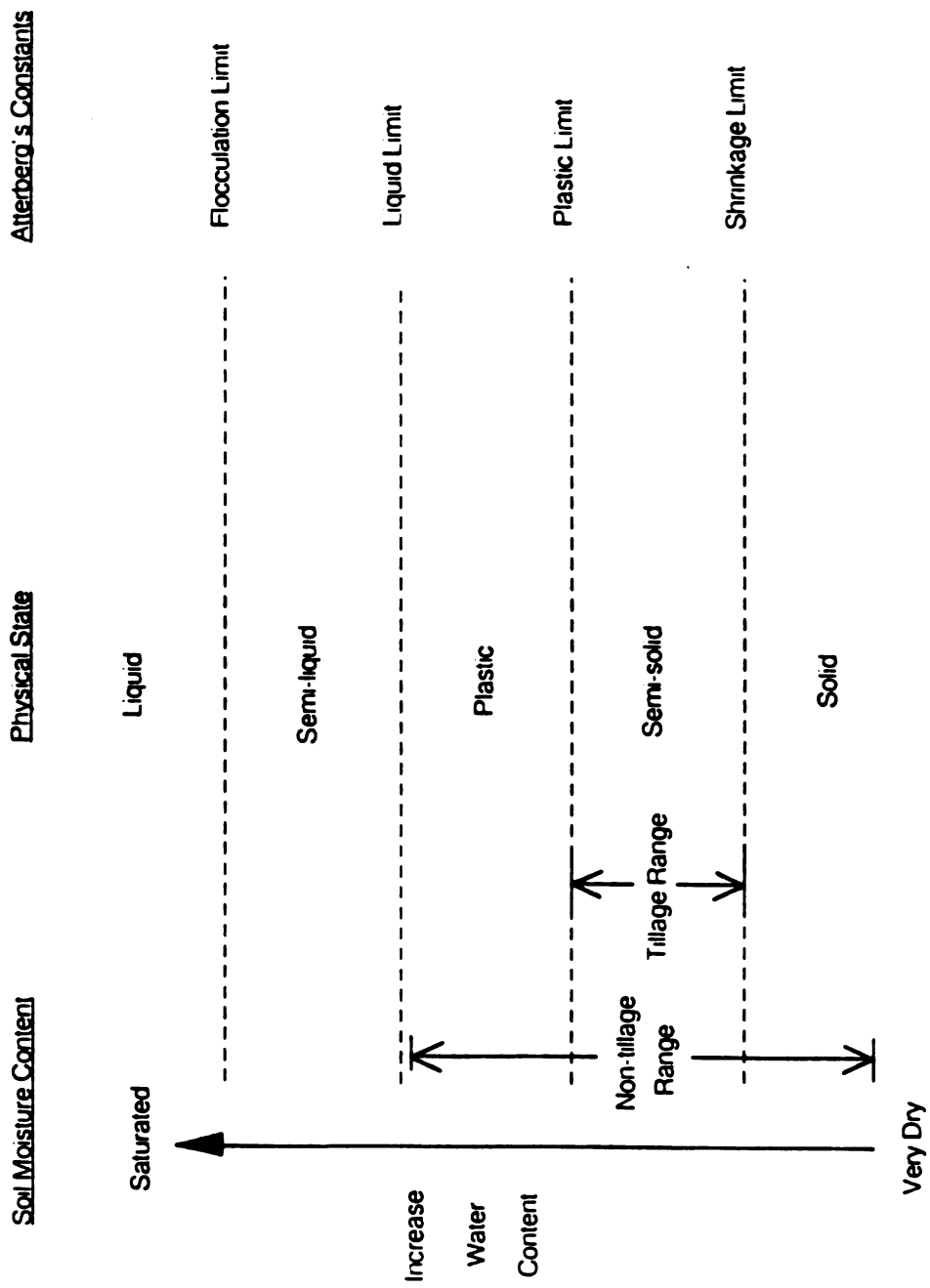


Figure 6. Atterberg consistency limits and their relation with field machinery operations

tilled at this moisture content it tends to crumble easily and form a loose assemblage of relatively small, soft clods (Hillel, 1980). At this condition, when the soil is tilled, more medium aggregates are formed (< 25 mm.), less soil impedance is created and normally the soil tends to have better structure for proper seed germination (Merino, 1977). Above this moisture content soil tends to be molded into lumps which, upon drying, become extremely hard and probably will experience structural deterioration. Figure 6 shows that the SMC of a workable day for tillage is less than the SMC of a tractable day for non-tillage operations.

3. Soil moisture content budget.

Several authors have reported PWD computations using the SMC budget as the most important criterion (Thorntwaite et al. 1954; Shaw, 1965; Selirio and Brown, 1972; Baier, 1972; Hassan and Broughton, 1975; Elliot et al., 1977; Dyer and Baier, 1979). All authors assume that weather events vary in a seasonal fashion.

Soil moisture status depends on the water holding capacity of the soil, initial moisture content and any moisture changes due to precipitation, runoff, evapotranspiration, infiltration, drainage, and diffusion.

The principal equation (Hunt, 1986) used in the computation of SMC is:

$$MOIST_n = MOIST_{n-1} - ET_n + RAIN_n - Q_n - DRAIN_n \quad [6]$$

where: $MOIST_n$ = SMC during day n , mm

$MOIST_{n-1}$ = SMC during day $n - 1$, mm

ET_n = evapotranspiration during day n , mm

$RAIN_n$ = precipitation during day n , mm

Q_n = runoff during day n , mm

$DRAIN_n$ = drainage during day n , mm

n = day number

Equation 6 is commonly modified for irrigation scheduling, evapotranspiration estimates, and other purposes.

Different types of soils have different water holding capacities depending on their texture, structure and the total pore spaces (soil matrix). The physicochemical state of soil water is characterized in terms of its free energy per unit mass, called potential (Hillel, 1980). Soil water potential describes the force with which soil moisture is bonded by the soil matrix. Water in the soil is in the form of a film surrounding the soil particles. The water film is thick when the soil moisture is high. At this moment the water is held at very low energy and is usually pulled out through the soil profile by gravity forces. As water is lost by evaporation or transpiration, this film reduces its thickness, increasing absorption forces between soil and water, causing the water to be less available for the

plants.

The energy of bonding of water to the soil matrix is usually expressed as the negative tension or suction, (-kPa) required to remove water from the soil. SMC is inversely proportional to the soil water potential. This functional relationship is graphically presented in the soil-moisture characteristic curve (See Figure 7).

Field capacity (FC) of a soil is that state where all of the free water in the pores has drained, but the water in the soil capillaries is retained against the pull of gravity. At this point the matric potential is low and more water is available for plants. Generally, matric potential for FC is taken to be -33 Kpa (1/3 bar).

The permanent wilting point (PWP) is that water content of the soil where plants cannot extract the remaining water in the soil (Hunt, 1986). This occurs when the matric potential is near -1500 Kpa (15 bars).

FC and PWP are respectively the maximum and minimum amounts of water that the soil can hold for plants. It is important to know these values because water evapotranspiration, runoff, drainage, and diffusion are functions of PWP and FC. The difference between the FC and PWP or the soil moisture content between -33 and -1500 Kpa is called available water capacity (AWC).

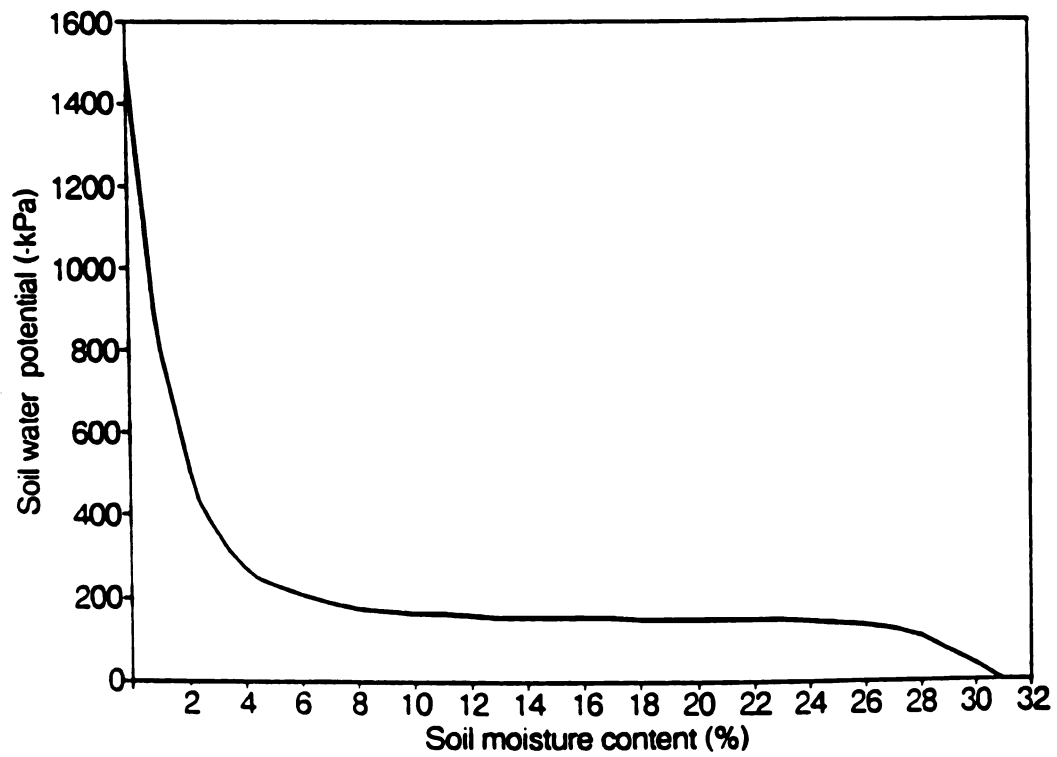


Figure 7. Example of a soil moisture-characteristic curve.

$$AWC = FC - PWP$$

[7]

Where: AWC = available water capacity, $m\ m^{-1}$ soil
depth

FC = field capacity, $m\ m^{-1}$ soil depth

PWP = permanent wilting point, $m\ m^{-1}$ soil
depth

After the soil and water relationship has been known, various terms should be defined in order to determine the SMC.

Precipitation. Water from precipitation is the most significant weather parameter that affects tractability or workability conditions of the soil. Precipitation is defined as the total measurable supply of water received directly from cloud as rain, snow, and hail (Farrall and Albrecht, 1965). In tropical areas, where rainfall is the only form of precipitation, the terms *rainfall* and *precipitation* have been used as synonymous.

Rain water has five possible destinations when it falls from clouds: 1) it is intercepted by plant canopy, 2) it runs off the soil surface if the infiltration rate of the soil is less than the intensity of rain, 3) it is lost by evapotranspiration through the plants and soil, 4) it is redistributed in the soil profile when the water in the soil is between FC and PWP , 5) it leaches to deeper layers when

the amount of water in the soil is greater than FC. Interception of rain by the plant canopy has been estimated to be 5-20% of the total precipitation (Lugo et al., 1981), but in general this amount is neglected for the purpose of SMC computation for PWD.

Evapotranspiration. The term evapotranspiration (ET) is defined as the evaporation from the soil surface and transpiration by the plants combined (Thorntwaite, 1948). When the SMC is below FC, water is lost from the soil only by ET. In this thesis term ET is equal to actual ET.

Thorntwaite (1948) introduced the term potential evapotranspiration (PET). The most widely accepted definition for PET was given by Penman (1956) as "the amount of water transpired in a unit of time by a short green crop, completely covering the ground, of uniform height and never short of water".

Methods used for estimating ET are classified in two categories: direct measurements of water evaporated, and those based on the use of meteorological data. Pan evaporation, soil moisture measurements, and lysimeters can be classified in the first group. Methods developed by Blaney and Criddle (1950), Thorntwaite (1948), Hargreave and Samani (1985), and Jensen (1966) are classified in the second group. These methods yield PET, except soil moisture measurements and lysimeters. Both groups have advantages and disadvantages but each needs to be evaluated locally in order to estimate ET confidently.

To account for the difference between PET and ET due to restriction on evapotranspiration imposed by crop species, crop growth stage, and crop density, a dimensionless parameter, crop coefficient K_c is utilized.

The most widespread direct method for estimating ET is Pan evaporation. The U.S. Weather Bureau Class A pan, which is well described by Jensen (1980), is widely used today. The equation used to estimate PET with this method is:

$$PET = E_p \times K_p \quad [8]$$

where: PET = potential evapotranspiration, mm/day
 E_p = evaporation from Class A pan, mm/day
 K_p = evaporation pan coefficient, no units

K_p is a coefficient used to calibrate pan evaporation and physical and environmental conditions around it. This coefficient is obtained from Doorembos and Pruitt (1977).

ET therefore can be calculated as:

$$ET = PET \times K_c \quad [9]$$

where: ET , PET , and K_c were previously defined.

Water infiltration. During rainfall, some of the water may enter through the soil surface by infiltration. The

water that enters the soil is equal to that portion of the rainfall that occurs at rates equal to or less than the infiltration rate of the soil (Thorntwaite, 1952).

Runoff. Runoff is that portion of the precipitation that makes its way toward stream, channels, lakes or oceans as surface or subsurface flow (Schwab et al., 1981). Surface runoff occurs when the intensity of the rainfall is greater than the infiltration rate of the soil or when the soil reaches its saturation point. From this point the term runoff will be used to refer surface runoff.

The most popular method of calculating daily runoff depth is the curve number (CN) method. It has been accepted worldwide because it has been used for many years in the USA, it is efficient, inputs are generally available, it is simple, and it relates surface runoff with soil type, soil infiltration rate, land use, and management practices. It was originated by the US Soil Conservation Service (SCS, 1972). This method has been modified by various researches for specific conditions and locations (Hawkins, 1978; Pathak et al., 1989).

Runoff is calculated from daily rainfall using the following relationship:

$$Q = \frac{(P - 0.2 S)^2}{P + 0.8 S} \quad [10]$$

$$Q = 0, \quad P < 0.2 S \quad [11]$$

where: Q = daily runoff, mm

P = daily rainfall, mm

S = linear index of watershed water storage, mm

SCS has determined the parameter S , evaluating antecedent moisture, soil conditions, land use, and conservation practices:

$$S = \left(\frac{25400}{CN} \right) - 254 \quad [12]$$

where: CN = is the parameter curve number varying from 0 to 100.

CN is related to a rough description of the watershed.

Drainage water. Drainage water is that water which the soil is unable to retain against the force of gravity. It is also called gravitational water, free water, or excess water (Farrall and Albrecht, 1965). It is the water in excess of the FC of the soil. This excess of water, in general, takes one or two days to drain out of the soil.

Diffusion water. It is the small amount of soil water that moves from one volume with high SMC to another with less SMC. During this process the water is redistributed in

the soil profile.

Maximum saturation. Saturation occurs whenever all pore spaces of a soil are completely saturated with water. This condition is seldom encountered under field conditions except immediately after a heavy rainfall. Shayya and Bralts (1991) suggested that maximum saturation for a soil is about 15 per cent over the FC.

Hygroscopic coefficient. This can be defined as the point where SMC is in equilibrium with atmospheric moisture. Although this point is affected by the relative humidity of the atmosphere it is approximately -3100 Kpa (31 bar).

4. Definition of a tractable and a workable day.

Each country and region has a unique climate and a unique type of soils. Different machine operations have different criteria as to what constitutes a working day. Wet soil and wet crops are usually deterrents to field operations (Section E.2).

The time available for tillage and non-tillage operations can be estimated if the SMC is determined for a given time. Soil with a high moisture content may lose its structure if it is traversed (Hillel, 1980; Lugo-Lopez and Acevedo, 1956).

Tractability and workability criteria for different soils have been reported by various researchers as were cited in the previous work section. From this research it

can be concluded that:

1. SMC in the first 15 cm layer is the most important moisture considered in the definition of a suitable day for field operations.
2. FC or AWC can be used as a reference value in the definition of a suitable day for field operations if the field operation criteria is expressed in the same terms.

For most mineral soils, the SMC for non-tillage operations is less than the liquid limit. Verigo and Razumova (1963) estimated the liquid limit for some soils in U.S.S.R near FC (.5 atm.)

Tillage operations criteria were defined as a moisture content near the plastic limit. Verigo and Razumova (1963) related the plastic limit with the hygroscopic coefficient by the following regression equation:

$$U = 1.28 U_h + 9.9 \quad [13]$$

where: U = plastic limit, kg kg⁻¹

U_h = hygroscopic coefficient, kg kg⁻¹

SCS soil surveys may report LL and PI values for a

given soil and soil depth (Gierbolini, 1979). These values can be used to obtain the approximated moisture content for tillage and non-tillage operations. Generally these are expressed in gravimetric percentage, kg kg^{-1} . Solving for PL in equation 5 then:

$$PL = LL - PI \quad [14]$$

Where: PL , LL , and PI are previously defined

Each soil has to be evaluated in order to approximate the proper soil moisture criteria for tractability and workability.

Weather also affects harvesting time. Degree of wetness in the crop due to rainfall may prohibit the harvesting operation because the quality of the crop deteriorates and the performance of the harvesting machine is reduced if it is harvested wet. Even if the soil is tractable, the crop possibly is not ready to be harvested. Alfalfa, for example, needs three consecutive tractable days after a non tractable day to be harvested (Wolak, 1981).

III. METHODOLOGY

Appropriate agricultural machinery selection and management, including scheduling of operations, depends to a high degree on the ability to predict working days in the field during various parts of the production season. Numerous studies have been carried out to meet the widely recognized requirement for this type of information and it is readily available for the major agricultural regions of the USA and Canada (Shaw, 1965; Tulu et al., 1974; Dyer and Baier, 1979)

In Puerto Rico, however, this kind of information is sorely lacking. It was, therefore, necessary to test various models for predicting Probabilities of Working Days (PWD) based on soil characteristics and available weather data to estimate the time available for different field operations used in vegetable production and sugarcane harvesting.

A. Research Approach.

The general approach to this research was to compare the applicability of the models presented by Hunt (1986), Tulu et al. (1974), and Babeir et al. (1986) for Puerto Rico

conditions. The following are the specific approaches used in this thesis.

Objective 1.

Test various models in the prediction of expected working days for different regions and crops of the south coast of Puerto Rico.

This was done using the models developed by Hunt, (1986), Tulu et al, (1974), and Babeir et al. (1986). These models were selected because they are simple, data are available for Puerto Rico, and they use different procedures to compute soil moisture content (SMC).

The Hunt (1986) model is the simplest method to compute SMC in the first 150 mm of the soil profile, using precipitation, runoff, evapotranspiration, and drainage as the only variables. In the second model (Tulu et al., 1974) the first 150 mm of soil profile is divided into three layers of different thicknesses. SMC is estimated for each layer, simulating water evapotranspiration from each layer. These new variables are in addition to those variables used by the Hunt (1986) model. In the Babeir et al. (1986) model the first 150 mm of soil profile is divided into three layers of equal thickness. In addition, this model uses a fourth 50 mm layer which ranges down to 200 mm in depth. Diffusion between layers are additional calculations in this model compared with the three layer model developed by Tulu et al.

(1974) .

Objective 2.

Select the best method for the estimation of probabilities of working days for the south coast of Puerto Rico.

Separate series of working-non working days were generated for each of three field operation categories. Simulation of different working days for field operation were compared with observed data for different locations (See Table 9). A validation of each model for each location was performed. Precision in the prediction of working days on a day to day basis for each month was also effected. Comparison between observed and simulated working days was done using linear regression. A sensitivity analysis was done to estimate parameters that best define each particular operation in a given location.

Objective 3.

Develop probabilities of working days (PWD) tables at different levels of probability, from available weather data for the south coast of Puerto Rico.

After the simulation models were shown to be valid in the prediction of working days then the best model was

Table 9. Selected locations according to crop type and field operations.

TYPE OF OPERATION AND CROP	LOCATION
Tillage operations on vegetable fields	Santa Isabel Valley
Non-tillage operations on vegetable fields	Santa Isabel Valley
Tillage operations on tomato fields	Santa Isabel Valley
Non-tillage operations on tomato fields	Santa Isabel Valley
Tillage operations on vegetable fields	Guanica Valley
Non-tillage operations on vegetable fields	Guanica Valley
Tillage operations on vegetable fields performed with crawler tractors	Guanica Valley
Sugarcane harvesting operations performed with combines	Santa Isabel Valley

selected to develop PWD's tables at different probability levels for each location. Sixteen years of weather data were used to develop PWD charts in a monthly basis. Three probability levels were chosen: 0.50, 0.75, and 0.94 in order to give confident information of the available working days. Criteria for these probability levels were 8 years with the highest predicted number of working days out of 16 years (0.50), 12 years with the highest predicted number of working days out of 16 years (0.75), and 15 years with the highest predicted number of working days out of 16 years (0.94).

B. Theoretical approach

One of the first objectives of this research was to compare the three PWD models. To do this some of the equations used in the original publications were modified to avoid marked differences between methods. For example, the SMC was computed for the first 150 mm of the soil profile for each method and SMC for deeper layers was not taken into account. Drainage and diffusion principles for calculating the SMC in each model was consistent with the original models. However, the computations for precipitation, runoff, infiltration, and evapotranspiration principles were similar for all models.

In the following sections the models used in this research are described first. Then working day criteria and

coefficients for field operations, assumptions, observed data, locations, and soil features are discussed.

1. Development of the models.

The development of the PWD models proceed in two major steps. In the first step the models generated sequences of working and non-working days based on 16 years of daily records of precipitation and pan evaporation obtained from the National Oceanic and Atmospheric Administration (NOAA, 1977-1992) for each location. An example of the weather input file is presented in Appendix A. To do this the models required crop and soil characteristics for each location and time of the year. The field operations were assigned according to the growing season on a monthly basis. Various output files were generated in order to compute the working days on daily, bimonthly or monthly basis. Examples of these output files are presented in Appendix A.

In the second step, the year was divided into months. The sequences of working days were summed for each selected month for each field operation category in order to establish estimates of the expected probabilities of working days at selected probability levels. A conceptual model and general flowchart of the PWD models used in this thesis are presented in Figures 8 and 9, respectively. Appendix B presents the computer program listing for each model.

Because the models proceeded in different ways to

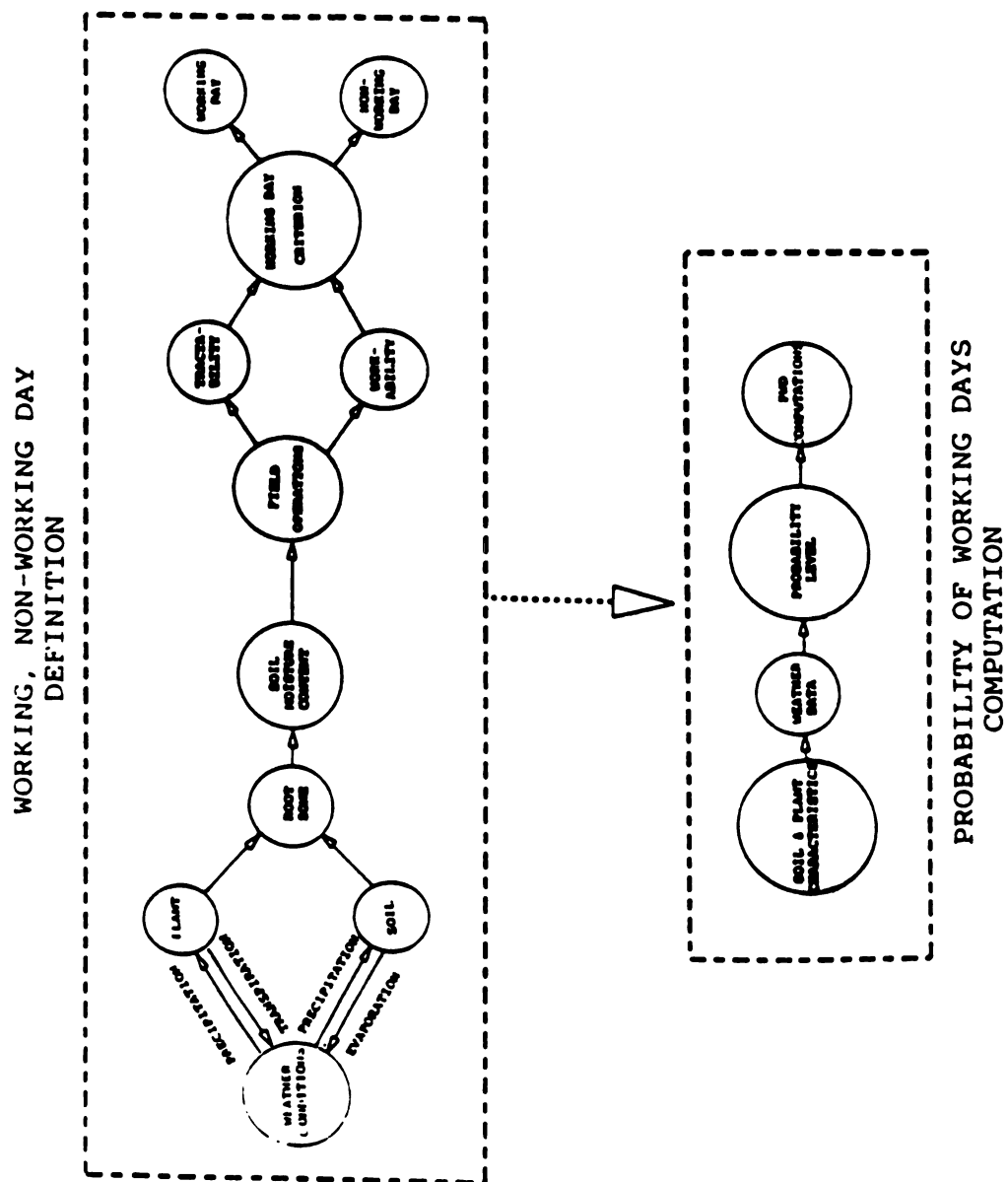


Figure 8. Conceptual model for the computation of PWD.

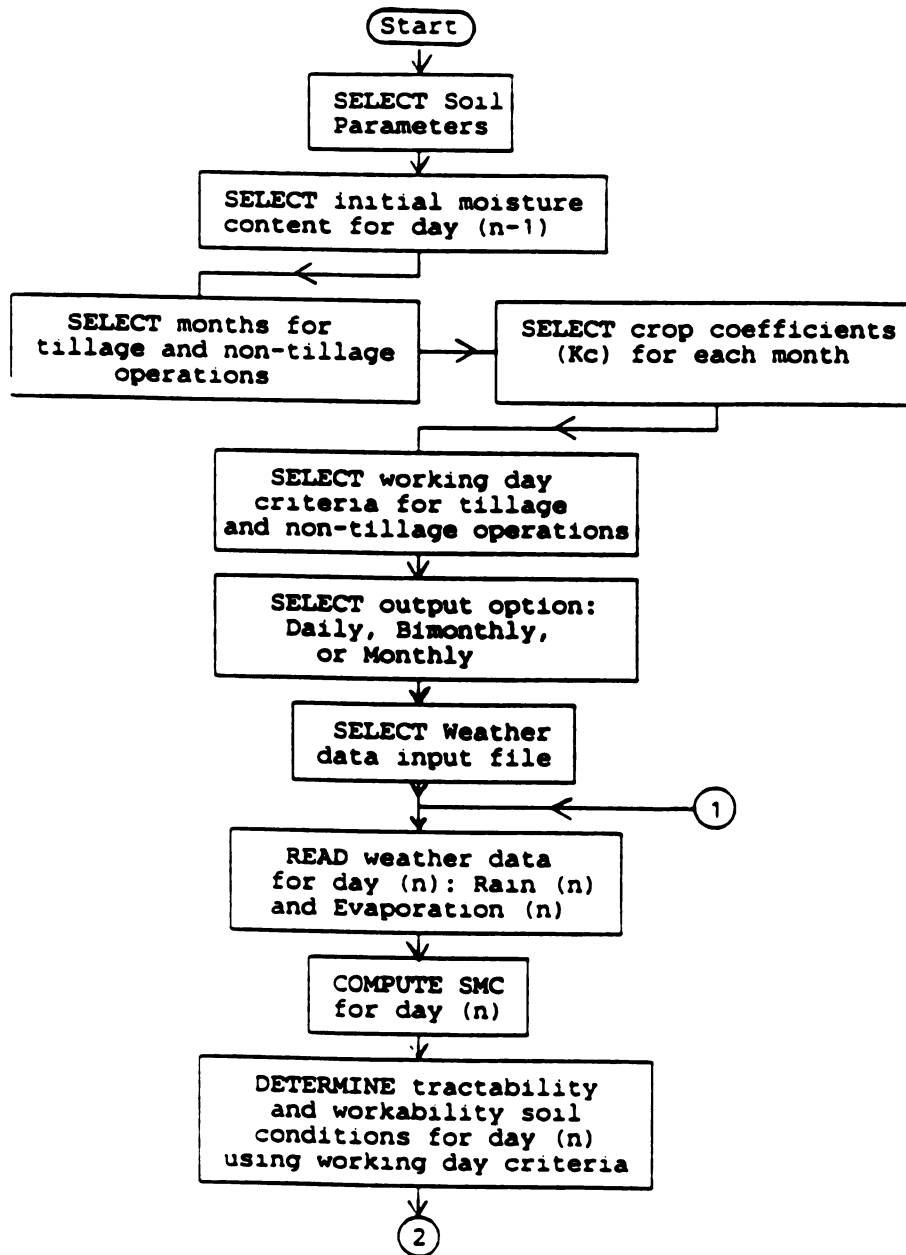


Figure 9. General flow chart for the computation of PWD.

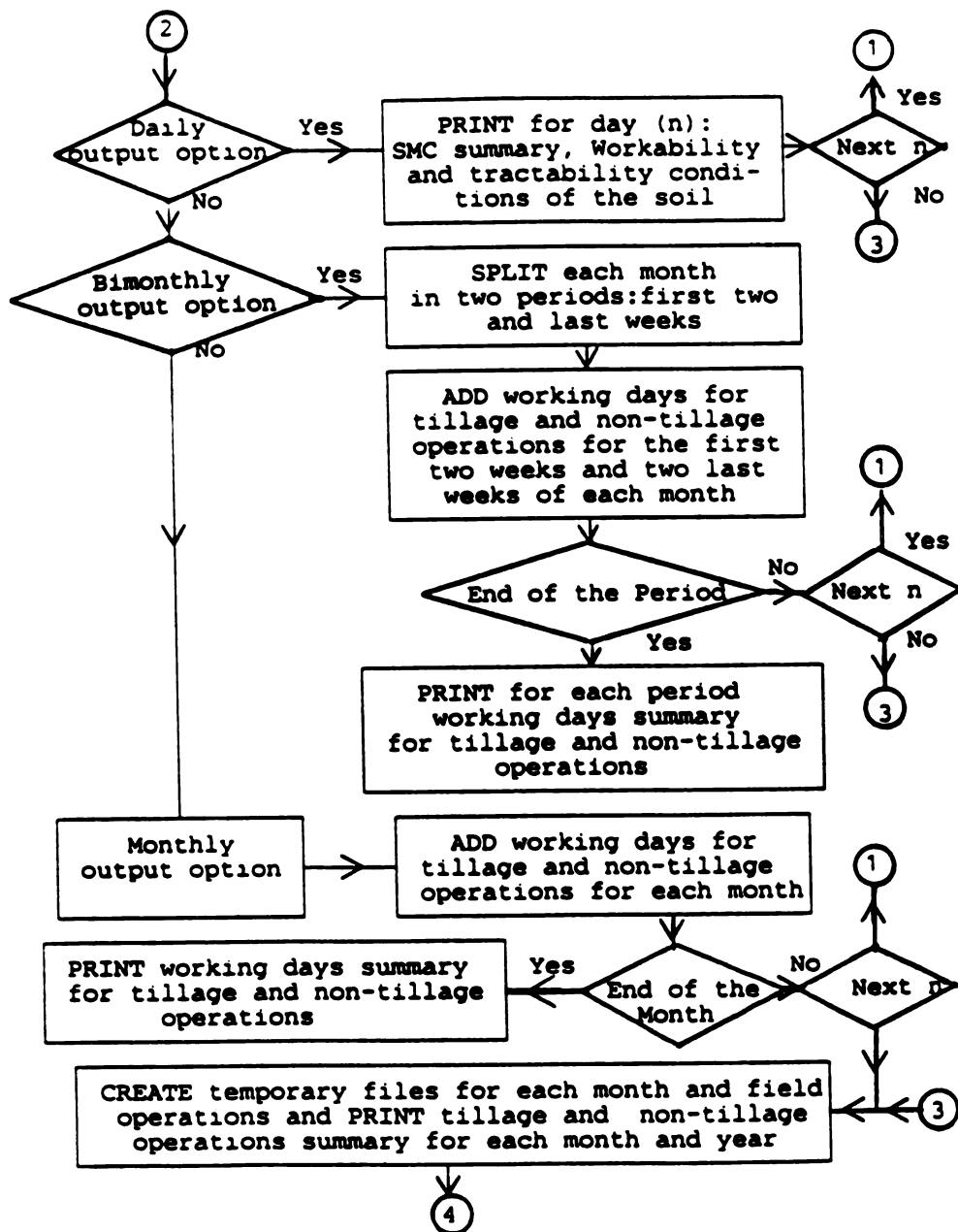


Figure 9. (cont'd).

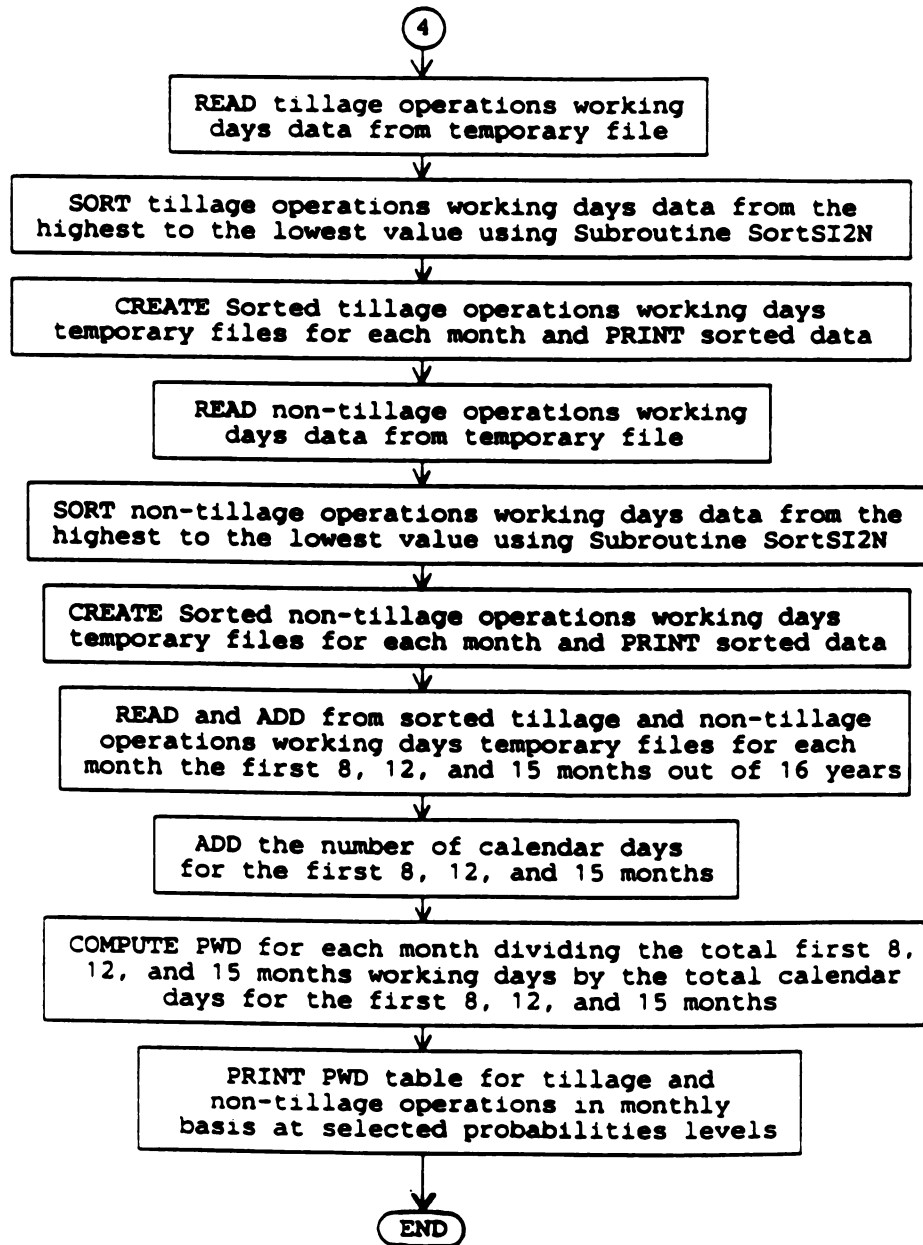


Figure 9. (cont'd).

compute SMC, the algorithms used by each model are discussed in the next sections separately.

a. Crop root zone assumptions.

The SMC computation was affected mainly by the rainfall and crop root zone. The root zone for vegetables under drip irrigation and covered with plastic mulch was found to be distributed mostly in the first 150 mm to 200 mm of the soil profile and extended laterally (Goyal, 1987; Knavel and Mohr, 1967). Transplanted tomatoes have a more superficial and active root system (lying in the first 30 cm) than when seeded directly according to Portas and Dordio (1980). It is a common practice to transplant vegetables in the south coast region of Puerto Rico; thus the root zone for vegetables was assumed to be shallow (150 mm).

Sugarcane root zone was assumed to be deeper than 150 mm. Barnes (1974) and Gomez (1970) reported that most of the sugarcane root branches occur in the top-soil to a depth of about 600 mm.

b. Modified Hunt (1986) model.

The Hunt model was originally developed for typical conditions in the midwestern US. In this model the SMC was estimated for one 150 mm layer of soil. No diffusion between this layer and deeper layers was assumed.

(1) Soil moisture computation.

A conceptual model and flowchart for SMC and plant relationship for the Hunt model (1986) modified for this thesis is presented in Figures 10 and 11, respectively.

The following equation was used by the modified Hunt (1986) model to compute SMC:

$$MOIST_n = IMOIST_{n-1} - ET_n + RAIN_n - Q_n - DRAIN_n \quad [13]$$

where: $MOIST_n$ = SMC during day n, mm

$IMOIST_{n-1}$ = SMC during day n - 1, mm

ET_n = evapotranspiration during day n, mm

$RAIN_n$ = precipitation during day n, mm

Q_n = runoff during day n, mm

$DRAIN_n$ = water drainage during day n, mm

a) Evapotranspiration - In the modified Hunt (1986) model the first water loss component during day n from the initial moisture content of day n-1 was assumed to be ET. Originally Hunt suggested the use of formulas based on temperature (Richey et al., 1961) to calculate daily ET. The use of class A pan evaporation (if available) for local computations of PET was suggested by Tulu et al. (1974) and Hetz et al. (1983). Sometimes, PET formulas derived from solar radiation and temperatures work well in temperate

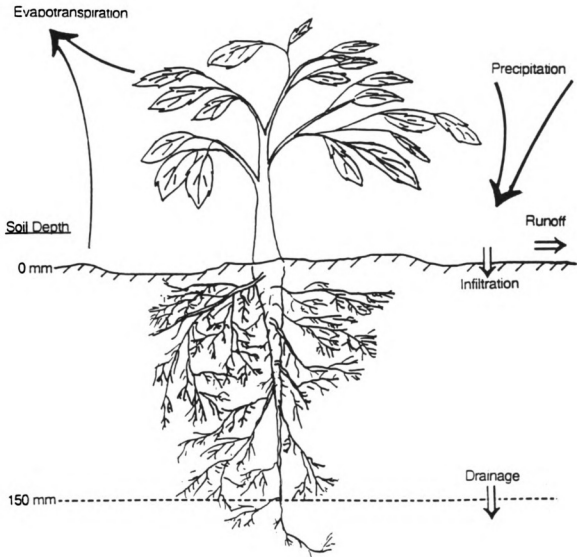


Figure 10. Conceptual model of the soil moisture content and plant relationship for Hunt (1986) model modified for this thesis.

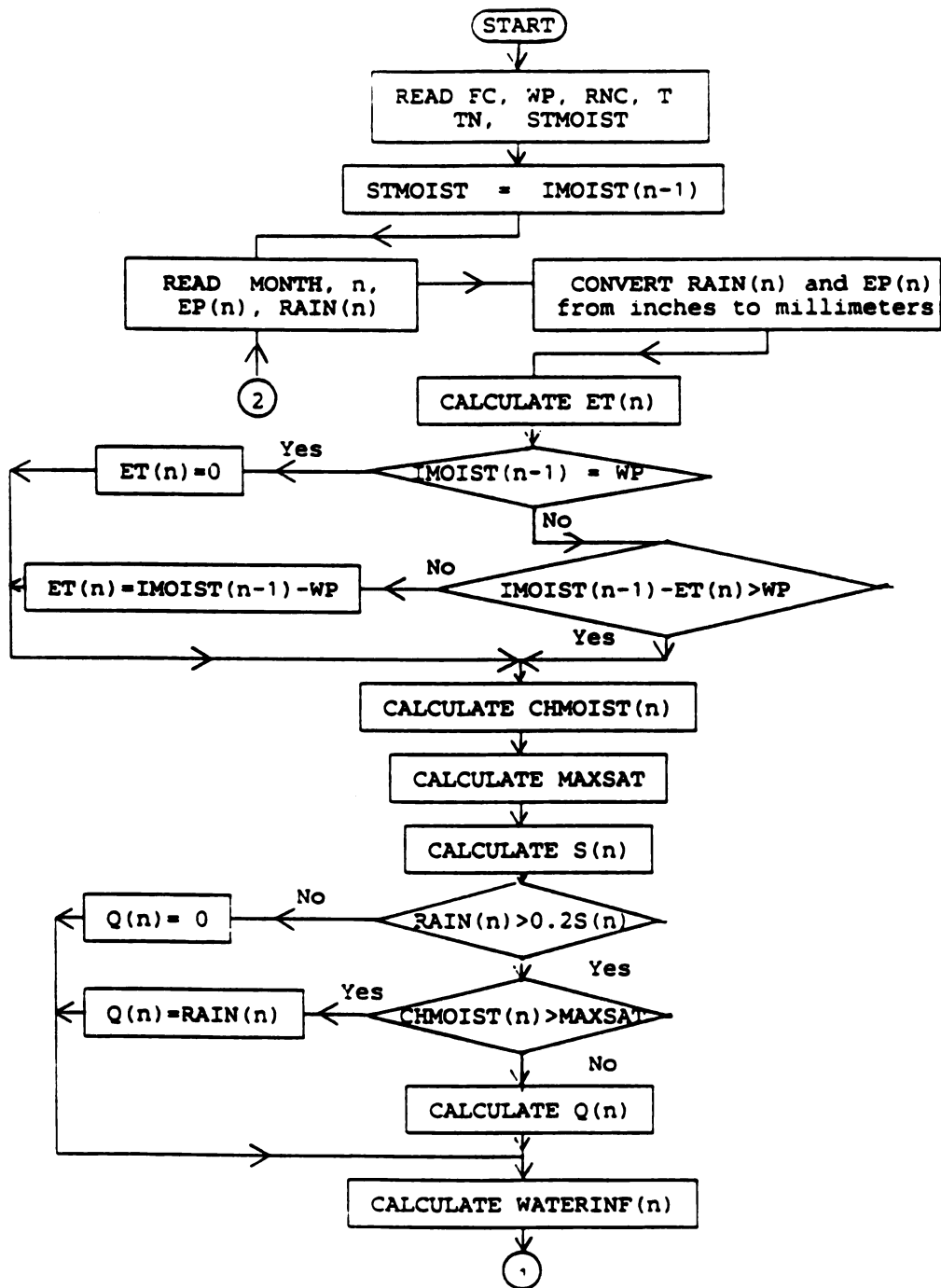


Figure 11. Flow chart of the soil moisture balance for the prediction of PWD based on Hunt (1986) modified model.

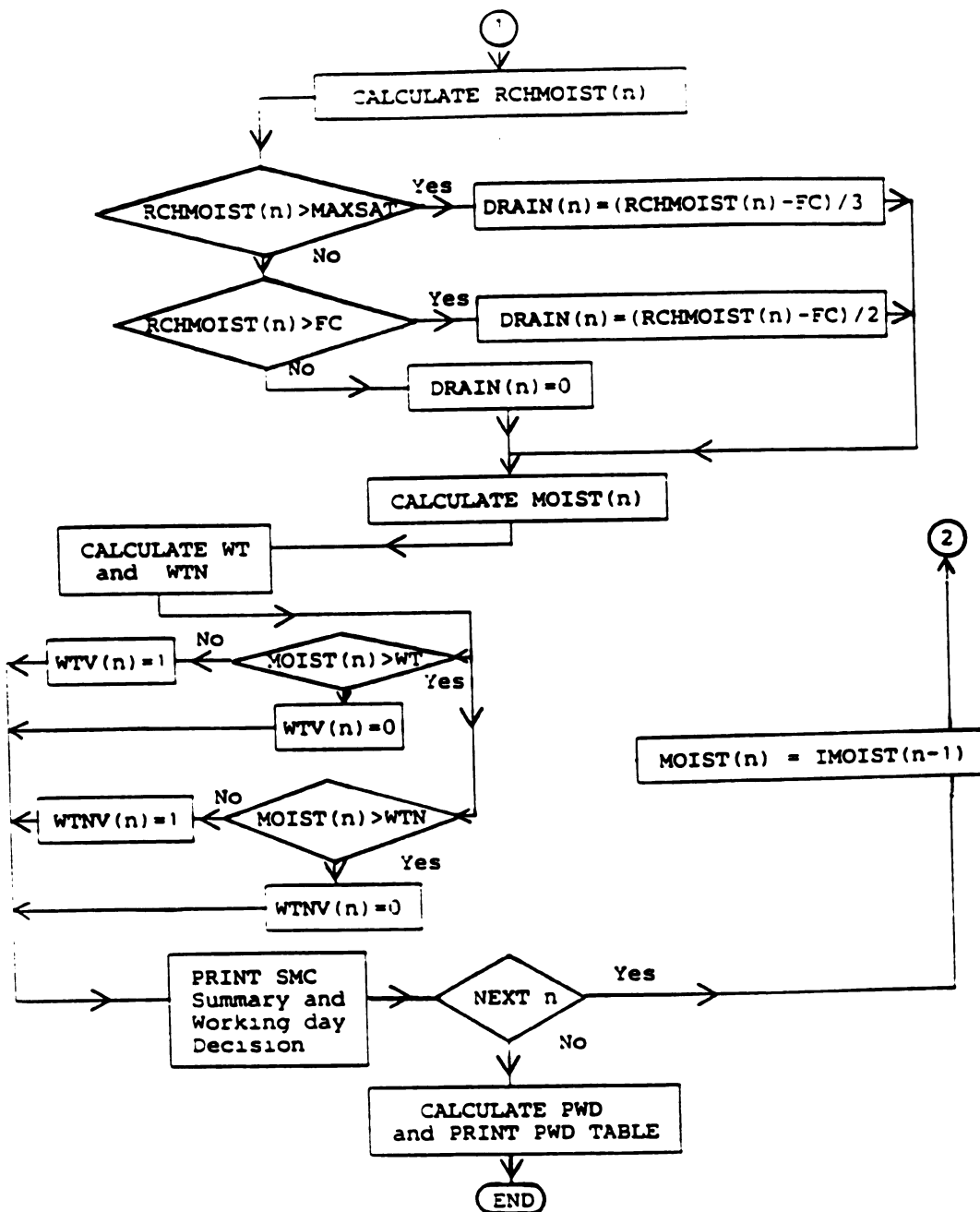


Figure 11. (cont'd).

climates where temperature changes and climatic conditions are extremes (IICA, 1985). These methods can predict ET confidently for intervals over 10 days.

Gonzalez and Goyal (1988) used the Hargreaves and Samani (1985) technique to compute PET for the estimation of corn water requirements in Fortuna Agricultural Experiment Station (south coast region). They suggested the use of this formula and compared its accuracy with other equations such as Doorenbos and Pruitt (1977), Penman, Blaney and Criddle, and the Class A evaporation pan. The Hargreaves and Samani (1985) technique estimated daily PET for Fortuna in a small range compared with PET computed using class A pan method (See Figure 12). This method did not estimate PET for extreme temperature conditions. For this reason, PET from the class A evaporation pan was utilized. The following relationship was used to calculate PET:

$$PET_n = Ep_n \times Kp \quad [14]$$

where: PET_n = potential evapotranspiration during
day n, mm

Ep_n = pan evaporation during day n, mm

Kp = evaporation pan coefficient,
dimensionless

Kp was the pan coefficient found by Doorenbos and Pruitt

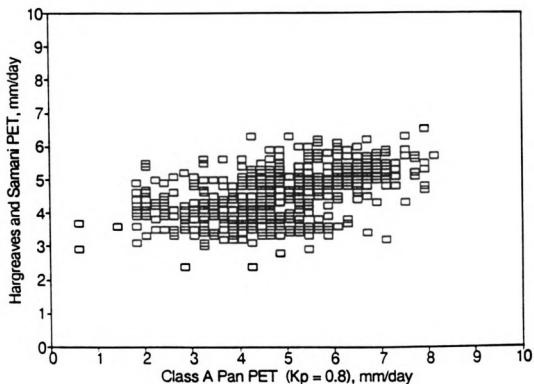


Figure 12. Comparison of PET calculated with the Class A pan evaporation method and Hargreaves and Samani (1985) method for the Fortuna Agriculture Experimental Station during the period of June 1989 to December 1990.

(1977). K_p of 0.80 which best describes the conditions of the weather stations of the agriculture experimental stations in the south coast of Puerto Rico. ET for vegetable and tomato crop field locations was determined with the following equation:

$$ET_n = PET_n \times Kc \quad [15]$$

where: ET_n = evapotranspiration during day n, mm
 PET_n = potential evapotranspiration during day n, mm
 Kc = crop growth coefficient, dimensionless

ET computed for the sugarcane fields location using equation 15 was multiplied by 0.60 to assume that only 60 per cent of the total ET was evapotranspired from the first 150 mm of the root zone and the other 40 percent from deeper layers. This relationship is shown in the following equation:

$$ET_n = PET_n \times Kc \times 0.60 \quad [16]$$

where: ET_n , PET_n , Kc , and n are previously defined

Kc was a crop coefficient used to estimate the crop water consumption during the growing season. Selected Kc 's for each location will be discussed later in location

aspects section.

ET was assumed to be zero if SMC in the layer during day $n-1$ was at PWP:

$$ET_n = 0, \quad IMOIST_{n-1} = WP \quad [17]$$

where: WP = permanent wilting point, mm

ET_n , $IMOIST_{n-1}$, and n , are previously defined.

The portion that can be lost by ET in days when ET was higher than SMC in the soil was equal to the total SMC above PWP. For this condition:

$$ET_n = IMOIST_{n-1} - WP, \quad IMOIST_{n-1} > WP \quad [18]$$

where: ET_n , $IMOIST_{n-1}$, n , and WP are previously defined.

b) Precipitation - The next component in the computation of SMC was precipitation ($RAIN_n$). Rainfall was considered the only form of water input for this and the next models. Drip irrigation is commonly used for vegetable production. Water from drip irrigation was assumed to not affect tractability due to the direct application to the crop bed at a low rate which does not wet the tractor tracks.

Furrow irrigation is discontinued at least one month

before starting the sugarcane harvest period, thus the soil was assumed to be near PWP at the beginning of this operation. In tropical weather, rain usually falls during the afternoon (Pico, 1974). Daily rainfall data is registered in various weather stations throughout the south coast and reported in NOAA (1976-1992).

c) Runoff - The third component in the computation of SMC was surface runoff (Q_n) from daily rainfall. This was estimated using the SCS (1972) CN technique modified by Pathak et al. (1989). This modified method was tested on a small watershed of Vertisol soils in India (semi-arid tropic). Q_n was predicted using the following equations:

$$Q_n = \frac{(RAIN_n - 0.2 S_n)}{RAIN_n + 0.8 S_n}, \quad RAIN_n > 0.2 S_n \quad [19]$$

$$Q_n = 0, \quad RAIN_n < 0.2 S_n \quad [20]$$

$$Q_n = RAIN_n, \quad CHMOIST_n > MAXSAT \quad [21]$$

where: Q_n = runoff during day n, mm

$RAIN_n$ = daily precipitation, mm

S_n = retention parameter related to soil
water content and antecedent moisture

content during day n

$MAXSAT$ = maximum saturation for the 150 mm
soil layer, mm

$CHMOIST_n$ = SMC after ET during day n , mm

S_n was calculated with equation 22 as:

$$S_n = (MAXSAT - CHMOIST_n) \times RNC \quad [22]$$

where: RNC = Runoff coefficient, no units

$MAXSAT$ and $CHMOIST_n$ are previously defined.

$CHMOIST_n$ was calculated with equation 23 as:

$$CHMOIST_n = IMOIST_{n-1} - ET_n \quad [23]$$

where: $IMOIST_{n-1}$, ET_n and, n are previously defined

Once maximum saturation was reached, water no longer entered the soil but instead was lost by surface runoff. Part of $RAIN_n$ was assumed to pond over the soil surface when $RAIN_n$ was higher than normal (e.g. $RAIN_n > 100$ mm). Maximum saturation ($MAXSAT$) was assumed to be 15% over the FC.

RNC was used to adjust Q_n for a given soil. When this model was originally tested (Pathak et al, 1989) in vertisols (swelling soil) RNC was taken to be 1.2. This

value was used for soil with cracks. In this thesis RNC was verified for all locations.

Other parameters were tested in the original work such as the effect of the soil moisture depletion on the formation of cracks, smoothness of the soil surface after rainfall, and roughness of the soil surface. These parameters should be locally calibrated. For this reason they were not considered in this research.

d) Infiltration - This was the fourth component in the computation of SMC. Water enters the soil after runoff has occurred. Infiltration was calculated with the following relationship:

$$WATERINF_n = RAIN_n - Q_n \quad [24]$$

where: $WATERINF_n$ = water infiltration for day n , mm

$RAIN_n$, Q_n , and n are previously defined.

e) Drainage - The fifth component calculated was drainage of water. The amount of water drained was assumed inversely proportional to PWP and proportional to the soil moisture above FC (Hunt, 1986). In this thesis, drainage of water occurred when SMC, after any change during day n , was over the FC of the soil layer. It was calculated with the following equations:

$$DRAIN_n = \frac{RCHMOIST_n - FC}{2} , \quad MAXSAT > RCHMOIST_n > FC \quad [25]$$

$$DRAIN_n = \frac{MAXSAT - FC}{3} , \quad RCHMOIST_n > MAXSAT \quad [26]$$

$$DRAIN_n = 0 , \quad RCHMOIST_n < FC \quad [27]$$

where: $DRAIN_n$ = water drainage during day n , mm

$RCHMOIST_n$ = SMC after rainfall during day n , mm

$RCHMOIST_n$ was calculated with equation 28 as:

$$RCHMOIST_n = CHMOIST_n + WATERINF_n \quad [28]$$

FC , $CHMOIST_n$, $MAXSAT$, $WATERINF_n$, and n are previously defined.

It is known that complete drainage of a saturated soil down to FC occurs in 48 hours (Hunt, 1986). For this condition equation 25 was used. The constant two (2) was used to allow this condition. Equation 26 was used when $RAIN_n$ represented a big rainstorm and SMC was over the maximum saturation.

The soil moisture content ($MOIST_n$) at any day was calculated then after drainage as follows:

$$MOIST_n = RCHMOIST_n - DRAIN_n \quad [29]$$

where: $MOIST_n$, $RCHMOIST_n$, $DRAIN_n$, and n are previously defined.

(2) Definition of field working day criteria.

After computation of SMC in the first 150 mm soil profile ($MOIST_n$), a day n was defined as a working or non working day for each field operation in each location. A field working day for tillage operations (WTV) and non-tillage operations ($WTNV$) was determined varying parameters in the model to determine which set of parameters best predicted working days during this research.

The working day criterion for tillage operations (WT) was expressed as a percentage of FC of the soil:

$$WT = \frac{T \times FC}{100} \quad [30]$$

where: WT = SMC working day criterion for tillage operations, mm

T = SMC percentage criterion for tillage operations, percentage

FC = field capacity, mm

A working day n for tillage operations was:

$$WTV_n = 1 , \quad MOIST_n < WT \quad [31]$$

A non working day n for tillage operation was:

$$WTV_n = 0 , \quad MOIST_n \geq WT \quad [32]$$

where: WTV_n = A field working day for tillage
operations, 1 or 0

$MOIST_n$ and WT are previously defined

The WTN criterion was also described as a percentage of
 FC of the soil:

$$WTN = \frac{TN \times FC}{100} \quad [33]$$

where: WTN = SMC working day criterion for non-tillage
operations, mm

TN = SMC percentage criterion for non-tillage
operations, percentage

FC = field capacity, mm

A working day n for non-tillage operations was:

$$WTNV_n = 1 , \quad MOIST_n < WTN \quad [34]$$

A non working day n for non-tillage operations was:

$$WTNV_n = 0 , \quad MOIST_n \geq WTN \quad [35]$$

where: $WTNV_n$ = A field working day (n) for non-tillage operations, 1 or 0

$MOIST_n$, WTN and n are previously defined.

Sugarcane harvesting was considered a non-tillage operation; thus equations 33, 34, and 35 were used in the definition of a working day for sugarcane harvesting.

c. Modified Tulu et al. (1974) model.

Tulu et al. (1974) divided the soil profile into three layers using the Rutledge and McHardy (1968) method to compute PWD on the northern part of Indiana. This model was tested in the prediction of working days for non-tillage operations. Working days for tillage operations were hypothesized.

(1) Soil moisture content computation.

The first layer occupied the 0.0 to 30 mm region.

Second and third layers were at the 30 mm to 75 mm and 75 mm to 150 mm depths respectively. This model as modified for this thesis included the same weather parameters used in Hunt model (See section B.1.b). A conceptual model of the SMC, layers and plant relationship for modified Tulu et al. (1974) model is presented in Figure 13. A flow chart is presented in Figure 14.

The general formula used for SMC in layer one was:

$$MOIST_{i,n} = IMOIST_{i,n-1} - ET_{i,n} + RAIN_n - Q_n - DRAIN_{i,n} \quad [36]$$

where: $MOIST_{i,n}$ = SMC of soil layer i during day n , mm

$IMOIST_{i,n-1}$ = SMC of soil layer i during day $n - 1$, mm

$ET_{i,n}$ = evapotranspiration from soil layer i
during day n , mm

$RAIN_n$ = precipitation during day n , mm

Q_n = runoff during day n , mm

$DRAIN_{i,n}$ = water drainage from soil layer i
during day n , mm

i = layer number, 1

n = number day

Because layer two and three did not receive water from rainfall directly but as drainage from layer one, the following formula was used in the computation of SMC:

$$MOIST_{i,n} = IMOIST_{i,n-1} - ET_{i,n} + DRAIN_{i-1,n} - DRAIN_{i,n} \quad [37]$$

where: $MOIST_{i,n}$ = SMC of soil layer i during day n , mm

$IMOIST_{i,n-1}$ = SMC of soil layer i during day
 $n - 1$, mm

$ET_{i,n}$ = evapotranspiration from soil
 layer i during day n , mm

$DRAIN_{i-1,n}$ = water drainage from soil layer
 $i - 1$ during day n , mm

$DRAIN_{i,n}$ = water drainage from soil layer i
 during day n , mm

i = layer number, 2 and 3

n = day number

a) Evapotranspiration - PET_n was calculated using daily class A pan evaporation as in the previous method with equation 14. ET from a particular layer was calculated using the following relationship:

$$ET_{i,n} = PET_n \times K_i \times Kc \quad [38]$$

Where: $ET_{i,n}$ = evapotranspiration from layer i
 during day n , mm

K_i = evaporation coefficient for layer i

i = layer number, 1, 2, and 3

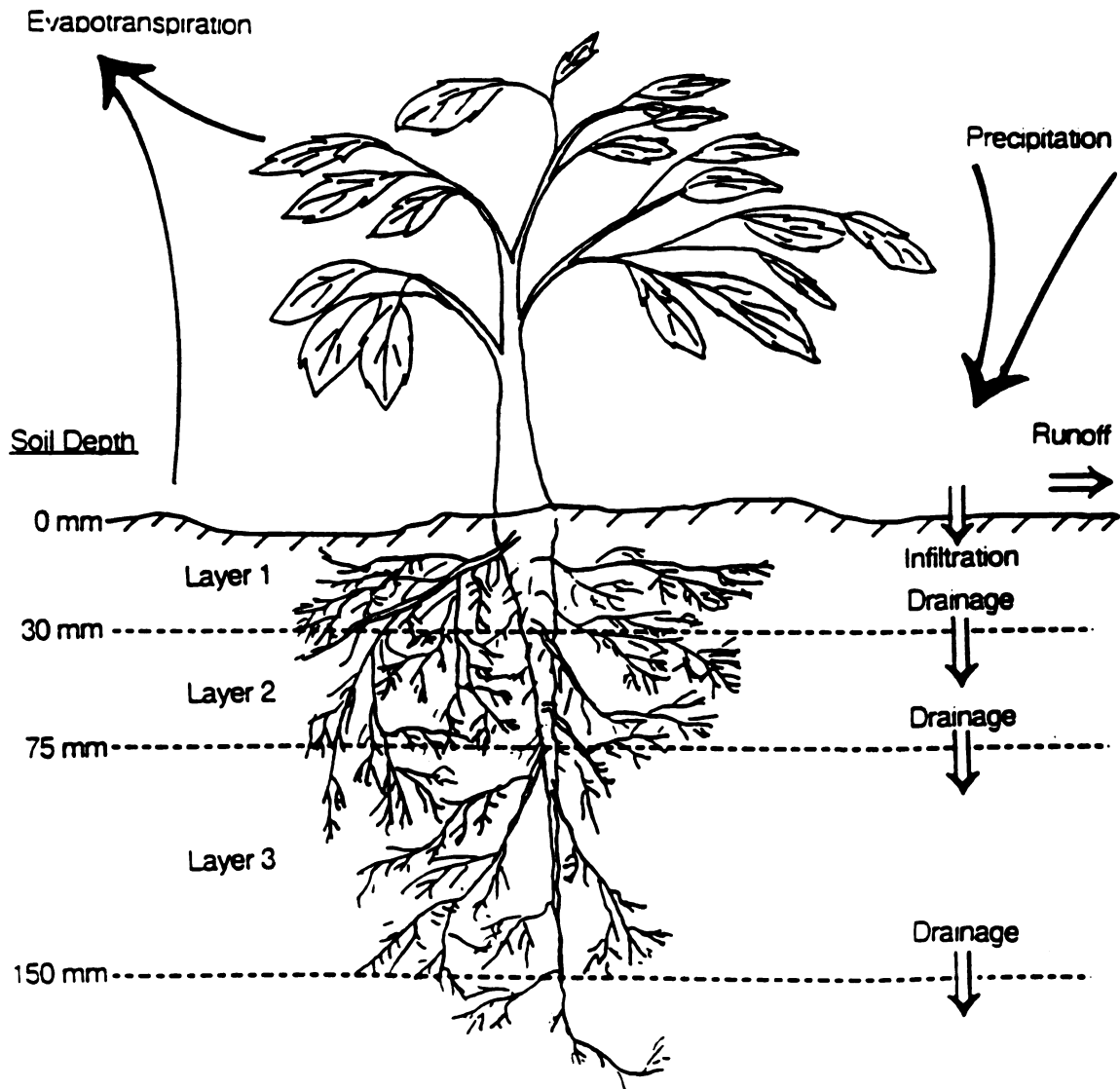


Figure 13. Conceptual model of the soil moisture content and plant relationship for Tulu et al. (1974) model modified for this thesis.

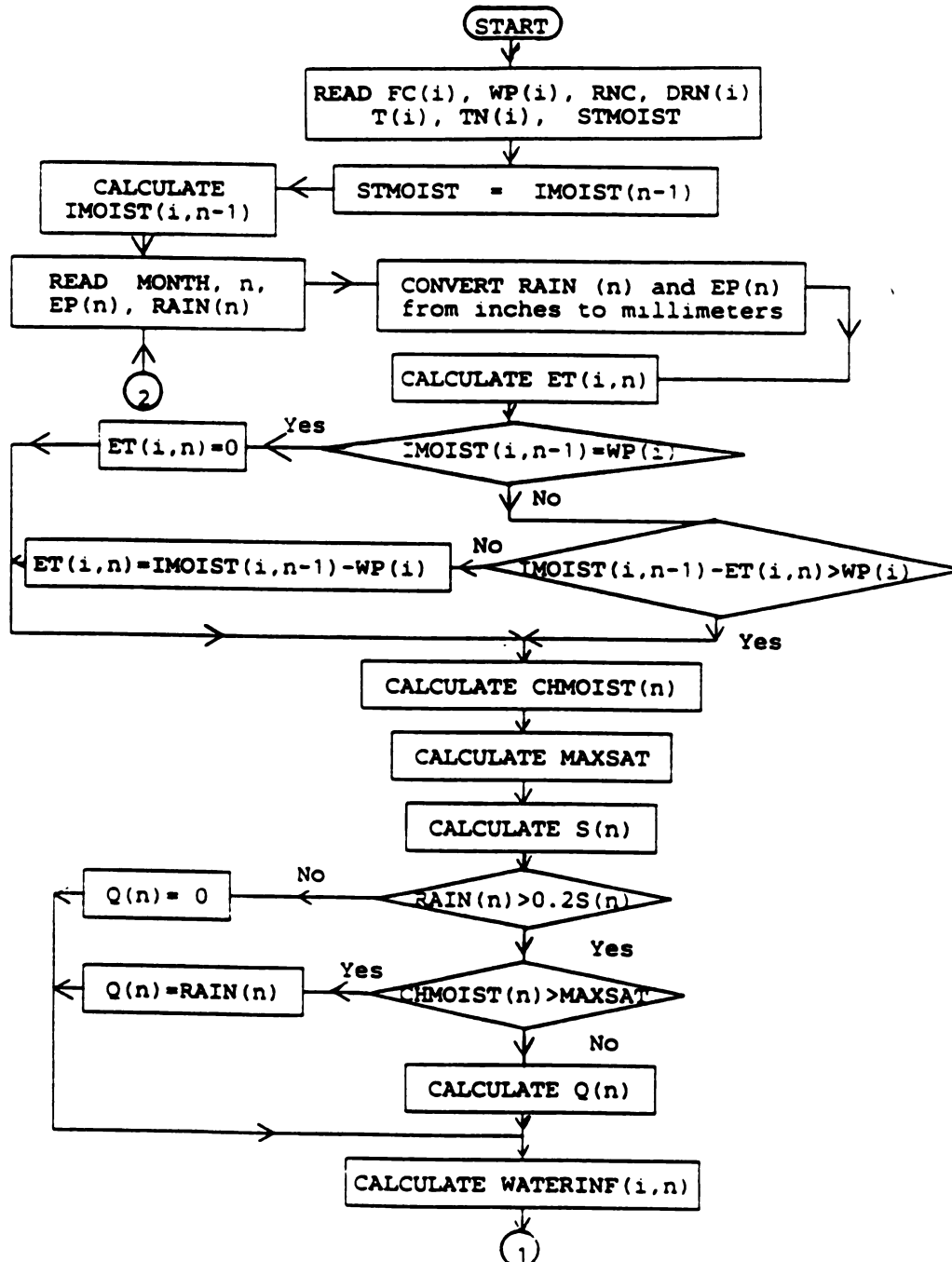


Figure 14. Flow chart of the soil moisture balance for the prediction of PWD for Tulu et al. (1974) modified model.

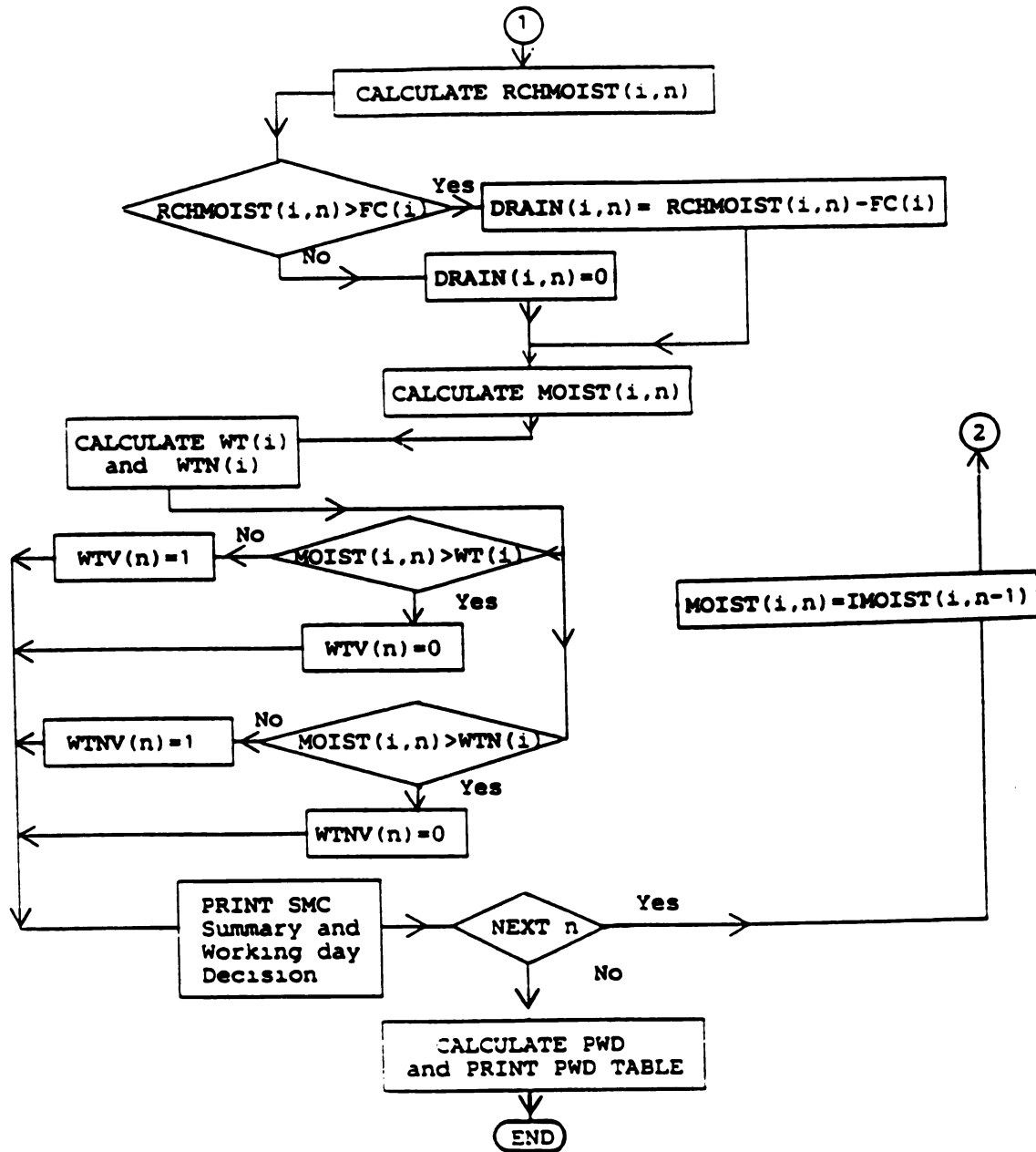


Figure 14. (cont'd).

PET_n , K_c , and n are previously defined.

The evaporation coefficient, K_i represented the fraction of ET that was evapotranspired from each layer. It was assumed that layer 1, which was directly affected by atmospheric weather factors (wind, solar radiation, and air temperature) contributed more than layers two and three. For that reason 0.55, 0.40, 0.05 were assigned for layers 1, 2, and 3 respectively (Tulu et al., 1974) when the model was tested on vegetable and tomato crop fields locations.

Due to a deeper root system in sugarcane field location the K_i were assumed to be 0.3, 0.2, and 0.1 for layers 1, 2, and 3 respectively. The other 40 percent was assumed to evapotranspire from deeper layers without affecting SMC in the first layers; thus it was not considered. In the original paper, Tulu et al. (1974) used a term T to adjust the amount of ET as a function of SMC in each layer. Assuming the same approach for ET discussed in section B.1.b.(1)a) T was not taken in account.

b) Precipitation _ This approach was explained in the first method (See section B.1.b.(1)b)).

c) Runoff - In the original paper, runoff was computed using Shaw's method (1963). In this thesis the SCS (1972) CN method as modified by Pathak et al. (1989), was used (See section B.1.b.(1)c)). Due to the computations of SMC by

layers, the term $CHMOIST_n$ was calculated adding the SMC of individual layers to obtain total SMC in the first 150 mm of soil profile after ET. This was considered in the estimation of S_n in runoff computation as follows:

$$Q_n = \frac{(RAIN_n - 0.2 S_n)^2}{RAIN_n + 0.8 S_n} \quad [39]$$

$$S_n = (MAXSAT - CHMOIST_n) \times RNC \quad [40]$$

where: $MAXSAT$ = maximum saturation for the first 150 mm of the soil profile, mm
 $CHMOIST_n$ = SMC in the first 150 mm soil profile after ET during day n , mm
 S_n , RNC , and n are previously defined.

$CHMOIST_n$ was calculated using the following equation:

$$CHMOIST_n = \sum_{i=1}^3 (IMOIST_{i,n-1} - ET_{i,n}) \quad [41]$$

where: $IMOIST_{i,n-1}$, $ET_{i,n}$, i , and n are previously defined

d) Infiltration - The same approach as described in the Hunt (1986) method was followed (See section B.1.b(1)d)).

In summary, layer one was the only layer that received water from rainfall. During infiltration, the first layer increased to FC. If drainage occurred, then water drained from the first layer to the second layer. Infiltration was calculated using the following equation:

$$WATERINF_{i,n} = RAIN_n - Q_n \quad [42]$$

where: $WATERINF_{i,n}$ = water infiltration into layer i
 during day n , mm
 i = layer number, 1
 $RAIN_n$, Q_n , and n are previously defined.

e) Drainage - The daily drainage calculations suggested by Tulu et al. (1974) were used here. Drainage of water occurs when SMC was over the FC of the referred layer. A drainage coefficient was used to adjust the daily amount of drainage on each layer. The following equations were used:

$$DRAIN_{i,n} = (RCHMOIST_{i,n} - FC_i) \times DRN_i, \quad RCHMOIST_{i,n} > FC_i \quad [43]$$

$$DRAIN_{i,n} = 0, \quad RCHMOIST_{i,n} < FC_i \quad [44]$$

where: $DRAIN_{i,n}$ = water drainage from layer i during
 day n , mm

$RCHMOIST_{i,n}$ = SMC change in layer i after
infiltration, mm

DRN_i = Drainage coefficient for layer i ,
(0 , 1)

FC_i = field capacity of layer i , mm

i = layer number, 2 and 3

For layer 1:

$RCHMOIST_{i,n}$ was calculated with equation 45 as:

$$RCHMOIST_{i,n} = CHMOIST_{i,n} + WATERINF_{i,n} \quad [45]$$

where: $RCHMOIST_{i,n}$ = SMC change in layer 1 after
infiltration, mm

i = layer number, 1

$CHMOIST_{i,n}$, $WATERINF_n$, and n are previously
defined.

For layers 2 and 3:

$RCHMOIST_{i,n}$ was calculated with equation 46 as:

$$RCHMOIST_{i,n} = CHMOIST_{i,n} + DRAIN_{i-1,n} \quad [46]$$

where: $RCHMOIST_{i,n}$ = SMC change in layer 2 and 3 after
ET and drainage from layers
 $i - 1$, mm

$DRAIN_{i-1,n}$ = water drainage from layer $i - 1$
during day n , mm

i = layer number, 2 and 3

$CHMOIST_{i,n}$ and n are previously defined.

Finally soil moisture content ($MOIST_{i,n}$) for each layer was calculated as:

$$MOIST_{i,n} = RCHMOIST_{i,n} - DRAIN_{i,n} \quad [47]$$

where: $MOIST_{i,n}$, $RCHMOIST_{i,n}$, $DRAIN_{i,n}$ i , and n are previously defined.

(2) Definition of field working day criteria.

Once SMC was computed for each layer ($MOIST_{i,n}$), a set of criteria was used to determine if the soil conditions were suitable for field operations. Same notation used in the first model WTV and $WTNV$ were used (See section B.1.b.2).

Working day criterion for tillage operations for the i^{th} layer (WT_i) was expressed as a percentage of FC_i :

$$WT_i = \frac{T_i \times FC_i}{100} \quad [48]$$

where: WT_i = SMC working day criterion for tillage
operations in layer i , mm

T_i = SMC percentage criterion for tillage
operations in layer i , percentage

FC_i = field capacity of layer i , mm

i = layer number, 1, 2, and 3

A working day n for tillage operations was:

$$WTV_n = 1, \quad MOIST_{i,n} < WT_i \quad [49]$$

A non working day n for tillage operations was:

$$WTV_n = 0, \quad MOIST_{i,n} \geq WT_i \quad [50]$$

where: WTV_n = A field working day (n) for tillage
operations, 1 or 0

$MOIST_{i,n}$ and WT_i are previously defined

WTN criterion was also defined as a percentage of FC of the
soil:

$$WTN_i = \frac{TN_i \times FC_i}{100} \quad [51]$$

where: WTN_i = SMC working day criterion for non-tillage
operations in layer i , mm

TN_i = SMC percentage criterion for non-tillage
operations in layer i , percentage

FC_i = field capacity of layer i , mm

i = layer number, 1, 2, and 3

A working day n for non-tillage operations was:

$$WTNV_n = 1, \quad MOIST_{i,n} < WTN_i \quad [52]$$

A non working day n for non-tillage operations was:

$$WTNV_n = 0, \quad MOIST_{i,n} \geq WTN_i \quad [53]$$

where: $WTNV_n$ = A field working day (n) for non-tillage
operations, 1 or 0

$MOIST_{i,n}$, WTN_i , i , and n are previously defined.

Sugarcane harvesting was considered as a non-tillage operation as in the previous model. Equations 51, 52, and 53 were used to define suitable days for this operation.

d. Modified Babeir et al. (1986) model.

In the original paper Babeir et al. (1986), named this model TRACTMOD. It was used to predict working days for non-tillage operations in Iowa. They divided the soil

profile into three layers of 150 mm thickness. SMC in the first two layers was considered in the prediction of working days. A new component was included in this model: diffusion between layers.

(1) Soil moisture content computation.

As was assumed in the first two models (Hunt, 1986; Tulu et al. 1974), modified for this thesis, the only zone considered in the computation of PWD was 150 mm. The soil profile was divided into three layers 50 mm thick each. A fourth layer of 50 mm thick was included in this model to simulate diffusion of water from a deeper layer. A conceptual diagram for Babeir et al. (1986) modified model of the soil profile and SMC computations is presented in Figure 15. A flowchart for the computation of PWD is also presented in Figure 16.

The principal SMC equation for layer 1 was:

$$MOIST_{i,n} = IMOIST_{i,n-1} - ET_{i,n} + RAIN_n - Q_n - DRAIN_{i,n} + DIFF_{i,i+1,n} \quad [54]$$

where: $MOIST_{i,n}$ = SMC of soil layer i during day n, mm

$IMOIST_{i,n-1}$ = SMC of soil layer i during day n - 1,
mm

$ET_{i,n}$ = evapotranspiration from soil layer i
during day n, mm

$RAIN_n$ = precipitation during day n, mm

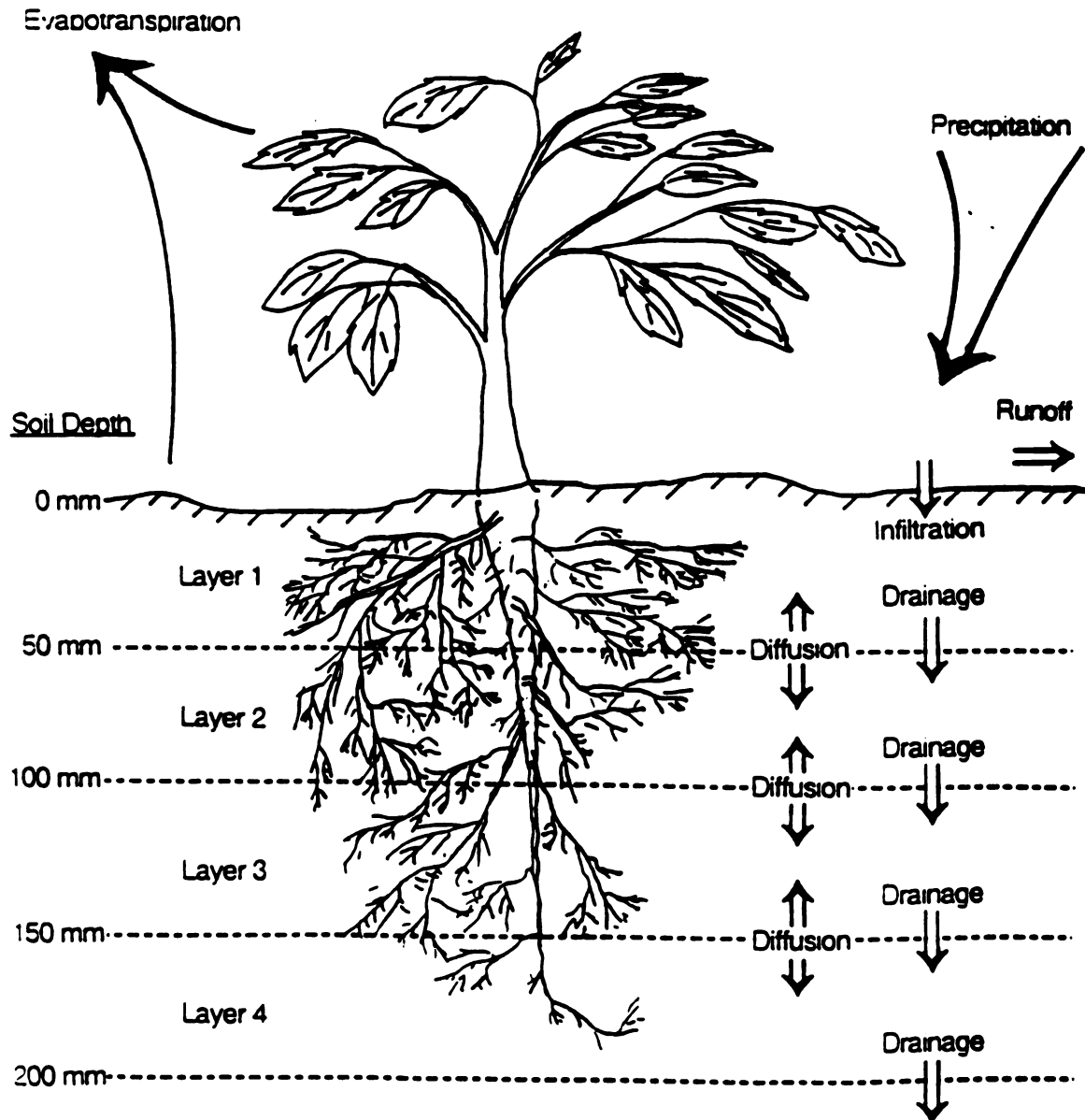


Figure 15. Conceptual model of the soil moisture content and plant relationship for Babeir et. al. (1986) model modified for this thesis.

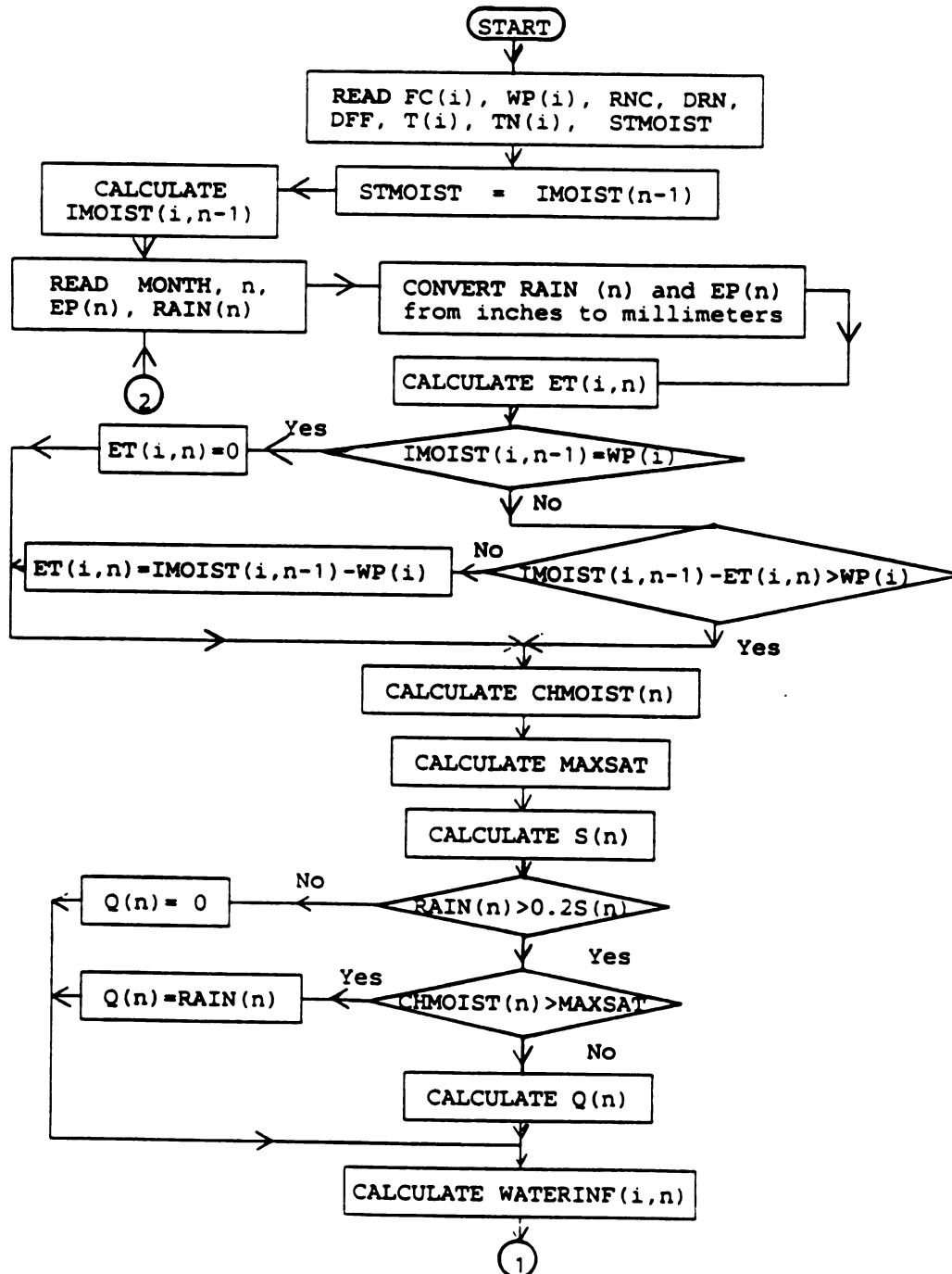


Figure 16. Flow chart of the soil moisture balance for the prediction of PWD for Babeir et al. (1986) modified model.

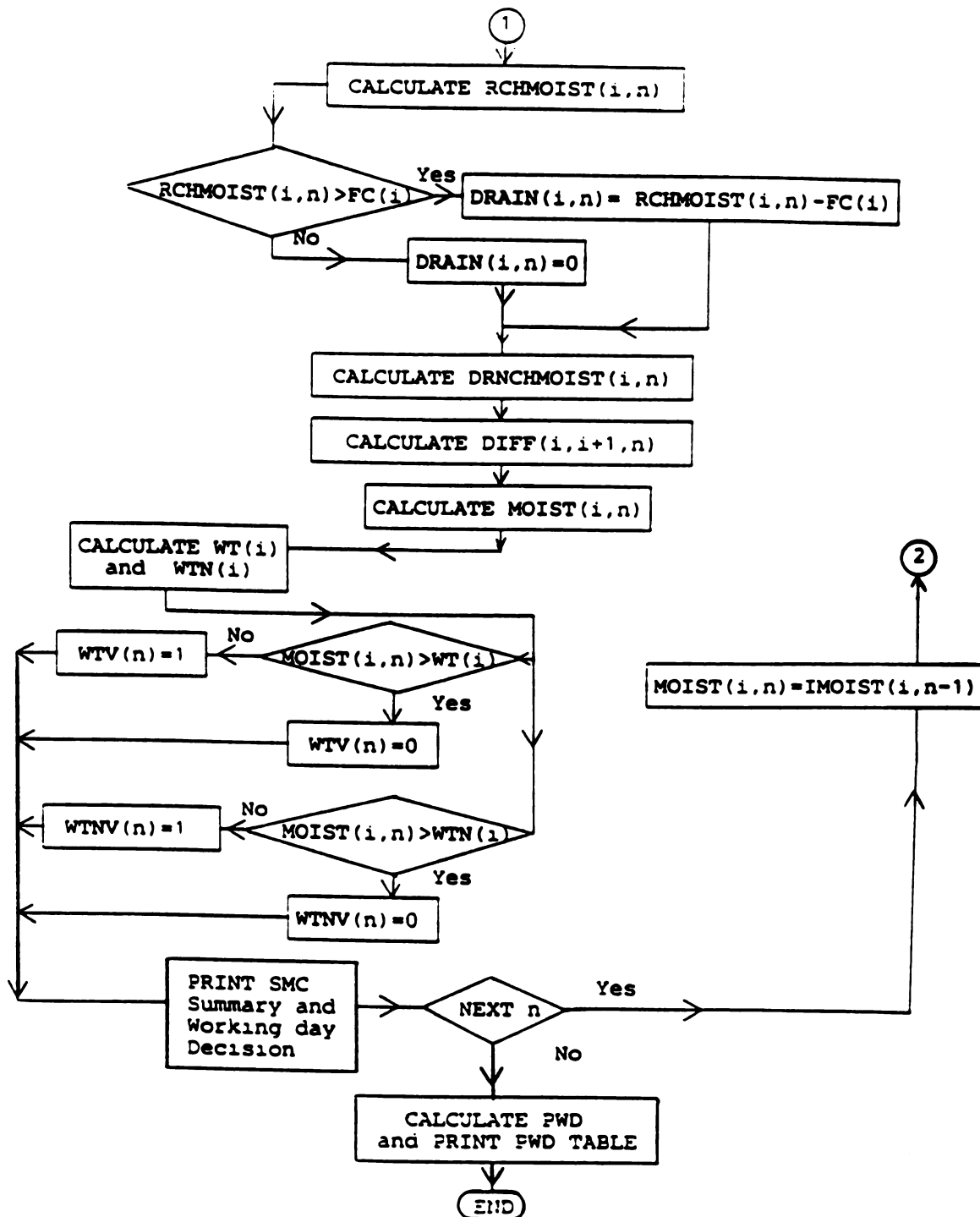


Figure 16. (cont'd).

Q_n = runoff during day n, mm

$DRAIN_{i,n}$ = water drainage from soil layer i
during day n, mm

$DIFF_{i,i+1,n}$ = water diffused between soil layers i
and i+1 during day n, mm

i = layer number, 1

n = day number

For layers 2 and 3:

$$MOIST_{i,n} = IMOIST_{i,n-1} - ET_{i,n} + DRAIN_{i-1,n} - DRAIN_{i,n} + DIFF_{i,i+1,n} \quad [55]$$

where: $MOIST_{i,n}$ = SMC of soil layer i during day n, mm

$IMOIST_{i,n-1}$ = SMC of soil layer i during day n - 1,
mm

$ET_{i,n}$ = evapotranspiration from soil layer i
during day n, mm

$DRAIN_{i,n}$ = water drainage from soil layer i
during day n, mm

$DRAIN_{i-1,n}$ = water drainage from soil layer i - 1
during day n, mm

$DIFF_{i,i+1,n}$ = water diffused between soil layers
i and i+1 during day n, mm

i = layer number, 2, 3 and 4

n = day number

a) Evapotranspiration - Some assumptions should be discussed in addition to those discussed in section B.1.c.(1).a) for this model. When this method was tested for vegetable and tomato crop fields locations, equation 38 was used to calculate daily ET. Because the layers in this model have different thickness compared with the Tulu et al. (1974) layers thickness, K_i were assumed as 0.60, 0.35, and 0.05 for layers 1, 2, and 3. ET from layer 4 was assumed as zero. In order to test the model in sugarcane crop, K_i were assumed as 0.3, 0.2, 0.1, and 0.1 for layers 1, 2, 3, and 4 respectively. The other 30% (0.3) was assumed to evapotranspire from deeper layers and were not considered.

b) Precipitation - Approaches followed in this model were the same as in the modified Hunt (1986) model (See section B.1.b.(1)b))

c) Runoff - In the original paper runoff was computed using Shaw's method (1965). This thesis adopts the approach used in the previous model (See section B.1.c.(1)c)). In the maximum saturation calculation only the first 150 mm of the soil profile (layers 1, 2, and 3) were considered.

d) Infiltration - Approaches followed in this model were the same as in the previous model (See section B.1.c.(1)d)).

e) Drainage - The approach followed in the previous model was used in this model. A common drainage coefficient for the three layers was used to adjust the daily amount of drainage. The following equations were used:

$$DRAIN_{i,n} = (RCHMOIST_{i,n} - FC_i) \times DRN, \quad RCHMOIST_{i,n} > FC_i \quad [56]$$

$$DRAIN_{i,n} = 0, \quad RCHMOIST_{i,n} < FC_i \quad [57]$$

where: $DRAIN_{i,n}$ = water drainage from layer i during day n , mm

$RCHMOIST_{i,n}$ = SMC change in layer i during day n , mm

FC_i = field capacity of layer i , mm

DRN = Drainage coefficient, (0 , 1)

i = layer number

For layer 1:

$RCHMOIST_{1,n}$ was calculated with equation 58 as:

$$RCHMOIST_{1,n} = CHMOIST_{1,n} + WATERINF_{1,n} \quad [58]$$

where: $RCHMOIST_{1,n}$ = SMC change in layer 1 after infiltration, mm

i = layer number, 1

$CHMOIST_{1,n}$, $WATERINF_n$, and n are previously

defined.

For layers 2, 3, and 4:

$RCHMOIST_{i,n}$ was calculated with equation 59 as:

$$RCHMOIST_{i,n} = CHMOIST_{i,n} + DRAIN_{i-1,n} \quad [59]$$

where: $RCHMOIST_{i,n}$ = SMC change in layer 2, 3, and 4
after ET and during drainage, mm

$DRAIN_{i-1,n}$ = water drainage from layer $i - 1$
during day n , mm

i = layer number, 2, 3, and 4

$CHMOIST_{i,n}$, and n are previously defined.

After all layers cease to receive drainage water from upper layers, the change in SMC was calculated newly with the following equation:

$$DRNCHMOIST_{i,n} = RCHMOIST_{i,n} - DRAIN_{i,n} \quad [60]$$

where: $DRNCHMOIST_{i,n}$ = SMC change after drainage ceases
from layer i during day n , mm.

$RCHMOIST_{i,n}$, $DRAIN_{i,n}$, i , and n are previously defined.

f) Diffusion - Procedure to compute diffusion between

layers was expressed as follows:

$$DIFF_{i,i+1,n} = \left[\frac{DRNCHMOIST_{i+1,n}}{FC_{i+1}} - \frac{DRNCHMOIST_{i,n}}{FC_i} \right] \times FC_{i+1} \times DFF \quad [61]$$

where: $DIFF_{i,i+1,n}$ = diffusion between layers i and $i + 1$
during day n , mm

$DRNCHMOIST_{i,n}$ = SMC after drainage in layer i
during day n , mm

$DRNCHMOIST_{i+1,n}$ = SMC after drainage in layer $i + 1$
during day n , mm

DFF = Diffusion coefficient, (0 , 1)

FC_i = field capacity of layer i , mm

FC_{i+1} = field capacity of layer $i + 1$, mm

i = layer number 1, 2, and 3

n = day number

When the term $DIFF_{i,i+1,n}$ was negative water diffuses to layer $i+1$ from layer i . If it was positive then vice-versa. No diffusion was assumed between layer 4 and deeper layers.

SMC for each layer during day n ($MOIST_{i,n}$) was finally calculated after diffusion with the following equation:

$$MOIST_{i,n} = DRNCHMOIST_{i,n} + DIFF_{i,i-1,n} \quad [62]$$

where: i = layer number, 1, 2, 3 and 4

$DRNCHMOIST_{i,n}$, $DIFF_{i,i+1,n}$ and n are previously defined.

(2) Definition of field working day criteria.

In this model a working day for field operations (WTV and $WTNV$) were assumed as defined in the previous model (See section B.1.c.(2)).

2. Validation of Models.

In order to validate the models, various sites in the south coast of Puerto Rico were selected (See Table 9) according to their relevance in agriculture and the availability of data. Soil type and soil moisture characteristics, crop production, number of farms, weather data, and other information was required to define each site accurately. Data sources and procedures are discussed in this section.

a. Soil characteristics.

"Moisture Relationships of Puerto Rican Soils" (Lugo, 1953) was used as a reference to obtain soil descriptive values needed to better characterize the soils of the particular regions during this study. This reference is a complete investigation of soil moisture characteristics for the most important soils of the island. South coast soils

reported in this paper were used principally for intensive sugarcane production but they have been used for vegetable production since the last decade.

Soil scientists recommended the use of a single reference (Gonzalez, 1993). Different research projects, even if performed in the same area, may observe different soil conditions; soil variability occurs in both space and time.

Each location was identified according to the number of farms, production area, or service area reported in the observed data. The most common soils used for crop production for each location were identified and located using SCS soil surveys (Carter, 1961; Gierbolini, 1979).

FC, WP, AWC, and HC for the first 150 mm of soil profile were obtained on a volume basis (Lugo, 1953) (See Table 10). Approximate values of the parameters were used to obtain a better description for each location. The values used for parameters for each location were not intended to represent specific soils but were taken from the range of values that would be appropriate for the soils (See Table 11).

b. Computation of soil moisture depth.

All models required input parameters for computation of soil moisture content expressed in depth of moisture (D_m), mm. The values acquired from Lugo (1953) were reported in volume percent (θ), m^3/m^3 , for the first 150 mm (6 in.) of

Table 10. Soil parameters for selected soils in the South Coast of Puerto Rico (Lugo, 1953).

Soil Parameter	Soil	
	San Anton Clay	Mercedita Clay
	(mm/150 mm)	
Field capacity	48.7	42.8
Permanent wilting point	27.9	25.3
Available water capacity	20.8	17.5
Maximum saturation	57.2	50.0
Hygroscopic coefficient	24.4	18.4

soil profile depth (D_s). To convert from θ to D_m the following step (Hillel, 1980) was followed:

$$D_m = D_s \times \theta \quad [63]$$

where: D_m = SMC depth, mm

D_s = soil profile depth, mm

θ = SMC in volume percent, m^3/m^3

c. Soil moisture sampling.

Samples were collected from the upper 150 mm of the soil to determine soil moisture in order to compare the

models' outputs. The soil moisture measurements were conducted during August 5 to August 8, 1992 at the Lajas Agriculture Experimental Station located on the Lajas Valley (See Figure 5). Two soils with different textures were considered: San Anton silty clay and Santa Isabel clay.

The San Anton silty clay (Mollisol) is composed of old alluvium (Carter, 1961). It occurs on slopes of 0 to 2 percent and has a friable Ap horizon, a moderate shrink-swell potential, and an AWC of 0.16 mm/mm. The San Anton soils are adjacent to the Fraternidad, Aguire, and Santa Isabel soils and are well drained.

The Santa Isabel clay (Vertisol) has a high shrink-swell potential, an AWC of 0.17 mm/mm and is composed of recent alluvium. Water moves through it slowly. It is slightly sticky and plastic when wet. It occupies concave slopes of 0 to 2 percent (SCS, 1961).

Seasonal high water table depths range from 0.92 m to 1.52 m (3 to 5 ft) for both soils.

Three areas (sites) were selected to take soil samples. The Santa Isabel soil was divided into two treatments (1) covered with plastic mulch but without a crop and (2) bare soil with some weeds. The row spacing in this field was 1.52 m (5 ft.). The San Anton silty clay site (3) had

Table 11. Soil parameters used by each modified model for all the locations.

Soil Parameter		Modified Model	
		Hunt (1986)	Tulu et al. (1974) Babeir et al. (1986)
Initial moisture content			
150 mm depth		30.0 mm/150 mm	30.0 mm/150 mm
Layer 1		--	9.0 mm/50 mm
Layer 2		--	9.0 mm/50 mm
Layer 3		--	12.0 mm/50 mm
Layer 4		--	12.0 mm/50 mm
Field capacity			
150 mm depth		45.0 mm/150 mm	45.0 mm/150 mm
Layer 1		--	15.0 mm/50 mm
Layer 2		--	15.0 mm/50 mm
Layer 3		--	15.0 mm/50 mm
Layer 4		--	15.0 mm/50 mm

(Table continued next page)

Table 11. (cont'd).

Soil Parameter	Modified Model		
	Hunt (1986)	Tulu et al. (1974)	Babeir et al. (1986)
Permanent wilting point			
150 mm depth	25.0 mm/150 mm	25.0 mm/150 mm	25.0 mm/150 mm
Layer 1	--	5.0 mm/30 mm	8.3 mm/50 mm
Layer 2	--	7.5 mm/45 mm	8.3 mm/50 mm
Layer 3	--	12.5 mm/75 mm	8.3 mm/50 mm
Layer 4	--	--	8.3 mm/50 mm
Available water capacity			
150 mm depth	20.0 mm/150 mm	20.0 mm/150 mm	20.0 mm/150 mm
Layer 1	--	4.0 mm/30 mm	6.7 mm/50 mm
Layer 2	--	6.0 mm/45 mm	6.7 mm/50 mm
Layer 3	--	10.0 mm/75 mm	6.7 mm/50 mm
Layer 4	--	--	6.7 mm/50 mm

pumpkins with a plastic mulch. Pumpkins were spaced 2.5 m (8 ft.) apart. At the time of sampling the pumpkins were in the fruiting stage.

The daily soil sampling was limited to an area of 10 m² in each site to minimize field variations (Diaz, 1992). Three samples were taken between rows (tractor tracks) using a 25.4 mm diameter type tube soil probe in each site during the afternoon. Samples taken on August 5 were used to obtain the initial soil moisture content. Soil moisture content was determined for the entire 150 mm of soil. Samples were taken from 0-50, 50-100, and 100-150 mm depths on August 6, 7, and 8. The soil moisture content was determined in dry weight basis.

Daily rainfall and evaporation data for the experimental area were obtained from a weather station (Lajas Substation No. 9097) each day at 7:00 a.m. The weather station was located approximately 1000 m from the experimental area. Two rainfalls occurred during the study; one on August 5 (7.0 mm) at 3:00 a.m. and reported in the same date and other on August 5 (26.0 mm) at 6:00 p.m. reported on August 6.

d. Field operations experimental areas.

The first and the second study of working days for tillage and non-tillage operations on vegetable and tomato field locations respectively, were conducted in Santa Isabel Valley. The third study for vegetable fields was performed

in Guanica Valley location. The models were tested by comparing their predictions with observed data of field working days from the SCVP located on Santa Isabel and Guanica valleys. Tractors used by the SCVP were mostly wheel type.

The fourth selected location was tillage operations performed with crawler tractors on vegetable fields for Guanica Valley. Observed data of field operations for this location was obtained from the "Centro de Maquinaria de la Administracion de Servicios Agricolas'" (ASA).

The fifth study was conducted at the Santa Isabel Valley location using data of sugarcane harvesting operations. Observed data was obtained from the Mercedita Sugarmill office located in the south coast region (Ponce city).

(1) Tillage and non-tillage operations on Santa Isabel Valley vegetable field locations.

a) Soil characteristics and location aspects. - The biggest area devoted to vegetable production under the South Coast Vegetable Program (SCVP) is located in Santa Isabel Valley (approximately 1500 ha). The production area is divided into approximately 40 farm plots. Farm plots size varies from 5 ha to 100 ha (Santiago, 1992). The outline of the area used for observed working days and the associated

¹Machinery Program of the Agricultural Services Administration

weather station locations is shown in Figure 17.

The normal annual precipitation for the Santa Isabel Valley is 836 mm with 58% falling in August to November.

The most typical soil series in the Santa Isabel and Guanica valleys are Cortada (Mollisol), San Anton (Mollisol) and Fraternidad (Vertisol). The texture of these representative mineral soils tends to be classified as silty clay loam, clay loam, and clay. Description of soils used in the Soil moisture sampling section describes also the soils of these location (See section B.2.c).

Reported soil parameters from Lugo (1953) for San Anton Clay and Mercedita Clay located in the south coast are shown in Table 10 and were used to identify the soil parameters in Santa Isabel and Guanica valleys.

b) Weather data. - Precipitation data was recorded and published in NOAA (1989-1992) for various weather stations in Santa Isabel Valley. Only two weather stations, Santa Isabel 2 ENE (No. 8940) and Ponce 4E (No. 7292), were used as a source of weather data for Santa Isabel Valley vegetable fields location (See Figure 17). Average rainfall depth over the area was used to compute daily rainfall (Schwab et al. 1981). Any day when rainfall data was unavailable on any of the weather stations, data from the nearest weather station, Ponce city (No. 7295) and Aguirre Central (No. 0152), was utilized.

Evaporation data was obtained from Ponce 4E (No. 7292)

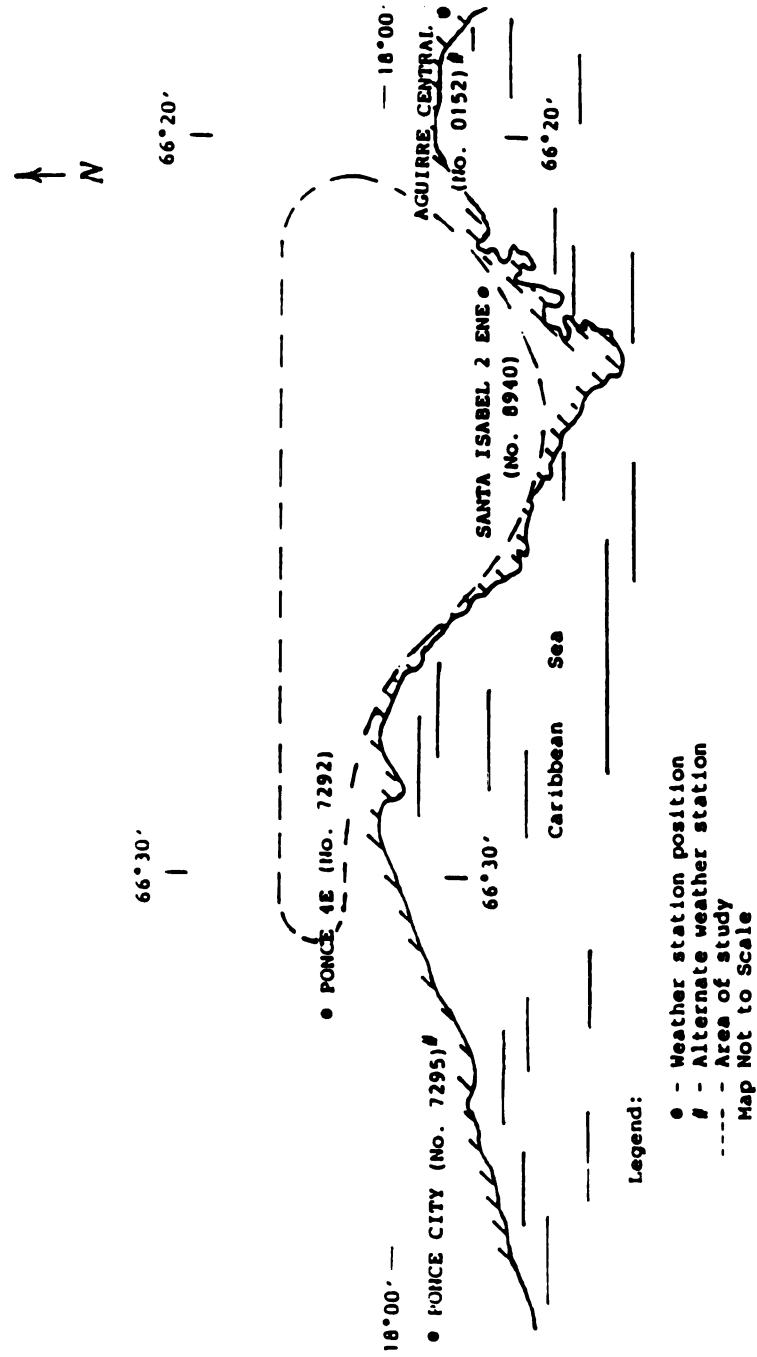


Figure 17. Santa Isabel valley vegetable fields location.

weather station located in Fortuna Agricultural Experiment Station and reported in NOAA (1989 - 1992). When evaporation data was missed, in this and the next tests, PET was calculated using the Hargreaves and Samani (1985) method suggested by Gonzalez and Goyal (1988). An arbitrary correction factor of 1.15 was used to adjust PET calculated with this method due to PET underestimation with this formula (See section B.1.b.(1)a))

c) Crop growing season. - Kc coefficients for Santa Isabel Valley vegetable fields location are presented in Table 12. These were used for daily ET computations and take into account the type of vegetable produced during the period of study (See Table 3) and values suggested by Doorembos and Pruitt (1977) as cited by Goyal (1988b). The most common periods for vegetable production from October to April were utilized (Agr. Exp. Sta, 1984). A Kc of 0.36 was used from May to September when the major fields were in bare conditions (Hetz et al., 1983).

(2) Tillage and non-tillage operations on Santa Isabel Valley tomato field locations.

Additional farms have been operated by the SCVP for tomato production in the Santa Isabel Valley (300 ha). The production area has 10 farm. Farm areas fluctuate from 15 ha to 150 ha (Santiago, 1992). This tomato production is

Table 12. Monthly Crop coefficients (Kc) used on each location.
(Goyal, 1988b; Goyal and Gonzalez, 1989b)

Location	Crop Coefficients (Kc)											
	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Santa Isabel Valley vegetable fields	0.95	1.00	0.80	0.80	0.36	0.36	0.36	0.36	0.36	0.50	0.60	0.90
Santa Isabel Valley tomato fields	1.00	1.00	0.80	0.80	0.36	0.36	0.36	0.36	0.36	0.50	0.70	0.90
Guanica Valley vegetable fields	0.95	1.00	0.80	0.80	0.36	0.36	0.36	0.36	0.36	0.50	0.60	0.90
Guanica Valley tillage operations performed with crawler tractors on vegetable fields	0.95	1.00	0.80	0.80	0.36	0.36	0.36	0.36	0.36	0.50	0.60	0.90
Santa Isabel Valley Sugarcane Harvesting operations performed with combines	0.96	0.79	0.73	0.59	0.77	0.36	0.93	1.06	1.09	1.10	1.09	1.05

exclusively operated by the SCVP agronomists. The farms are located in the eastern part of the valley (See Figure 18).

a) Soil characteristics and location aspects. - Soils described in the Santa Isabel vegetable field locations were used to describe the soils for this location.

b) Weather data. - Santa Isabel 2 ENE (No. 8940) weather station was used to obtain daily rainfall data for Santa Isabel Valley tomato field locations. Any day when rainfall data was missed, data from Arroyo Central (No. 0152) weather station was utilized. Evaporation data was obtained from Ponce 4E (No. 7292) weather station.

c) Crop growing season. - Crop coefficient, K_c , for the computation of ET in Santa Isabel Valley tomato fields location are presented in Table 12 (Doorembos and Pruitt (1977) cited by Goyal (1988b)). These monthly values were assumed for a growing season from October to April. This long growing season was assumed because the exact planting time was not reported. Bare conditions were assumed during May to September.

(3) Tillage and non-tillage operations on Guanica Valley vegetable field locations.

SCVP is also using the Guanica Valley for vegetable

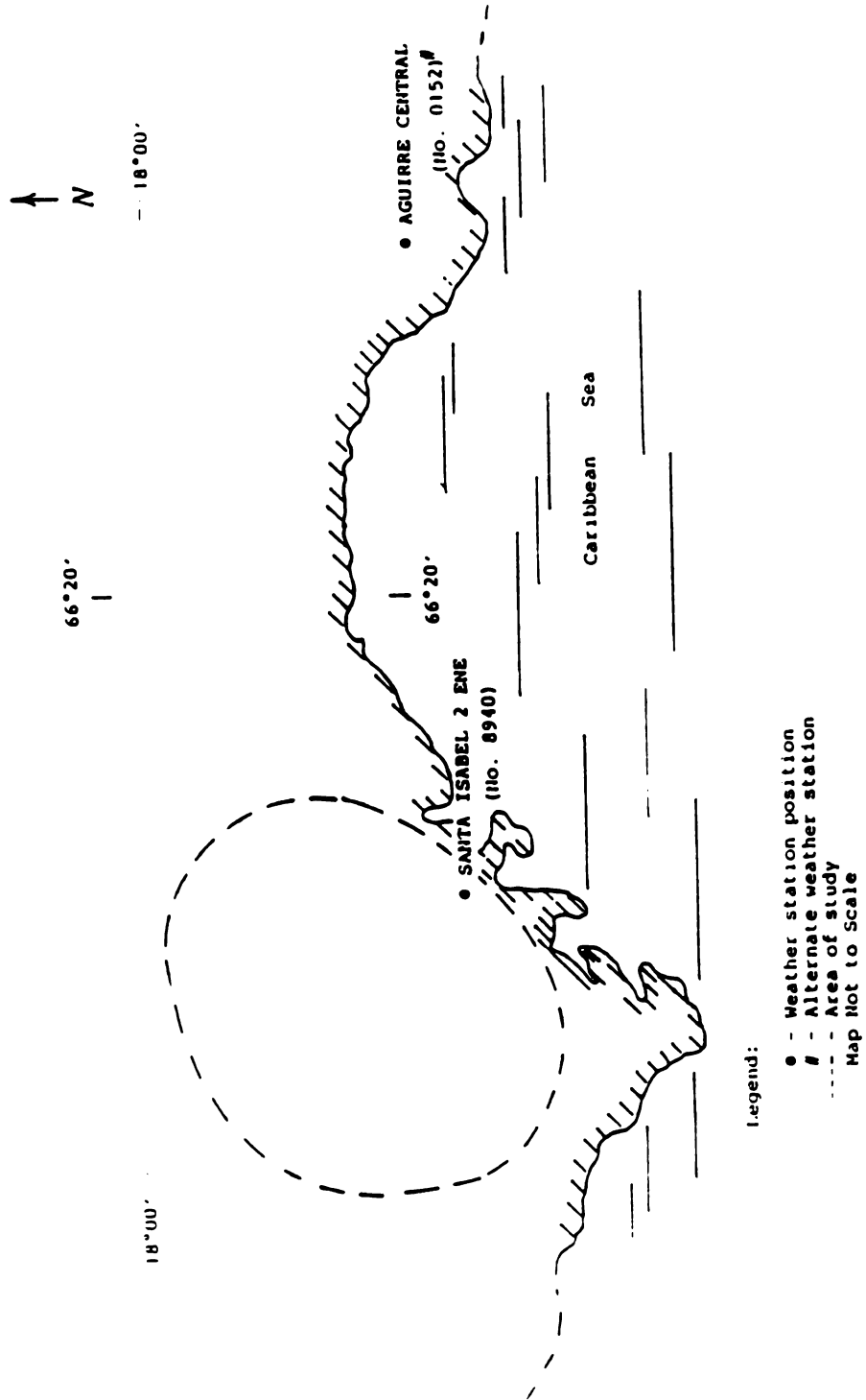


Figure 18. Santa Isabel Valley tomato fields location.

production. Production area covered by this project is approximately 300 ha (See Figure 19). The area is divided into 20 farm plots varying in size from 5 ha to 100 ha approximately (Santiago, 1992).

a) Soil characteristics and location aspects. - Soils described in the Santa Isabel Valley vegetable field locations were used to describe the soils for this location. Annual normal precipitation for the Guanica Valley is 854 mm of which 51% falls between August to November.

b) Weather data. - For the Guanica Valley vegetable field locations, daily rainfall values recorded from Santa Rita weather station (No. 8995) were used. Ensenada (No. 3532) weather station was used as alternate weather station when rainfall data was not available. Evaporation data was obtained from the Lajas Substation (No. 5097) weather station located 20 km west of the location area.

c) Crop growing season. - Table 12 shows crop coefficients for this area (Doorembos and Pruitt (1977) cited by Goyal (1988b)). These were based on the most common vegetable cultivated in the area during the period of this study (See Table 4). Growing period was assumed the same as the Santa Isabel Valley vegetable field locations.

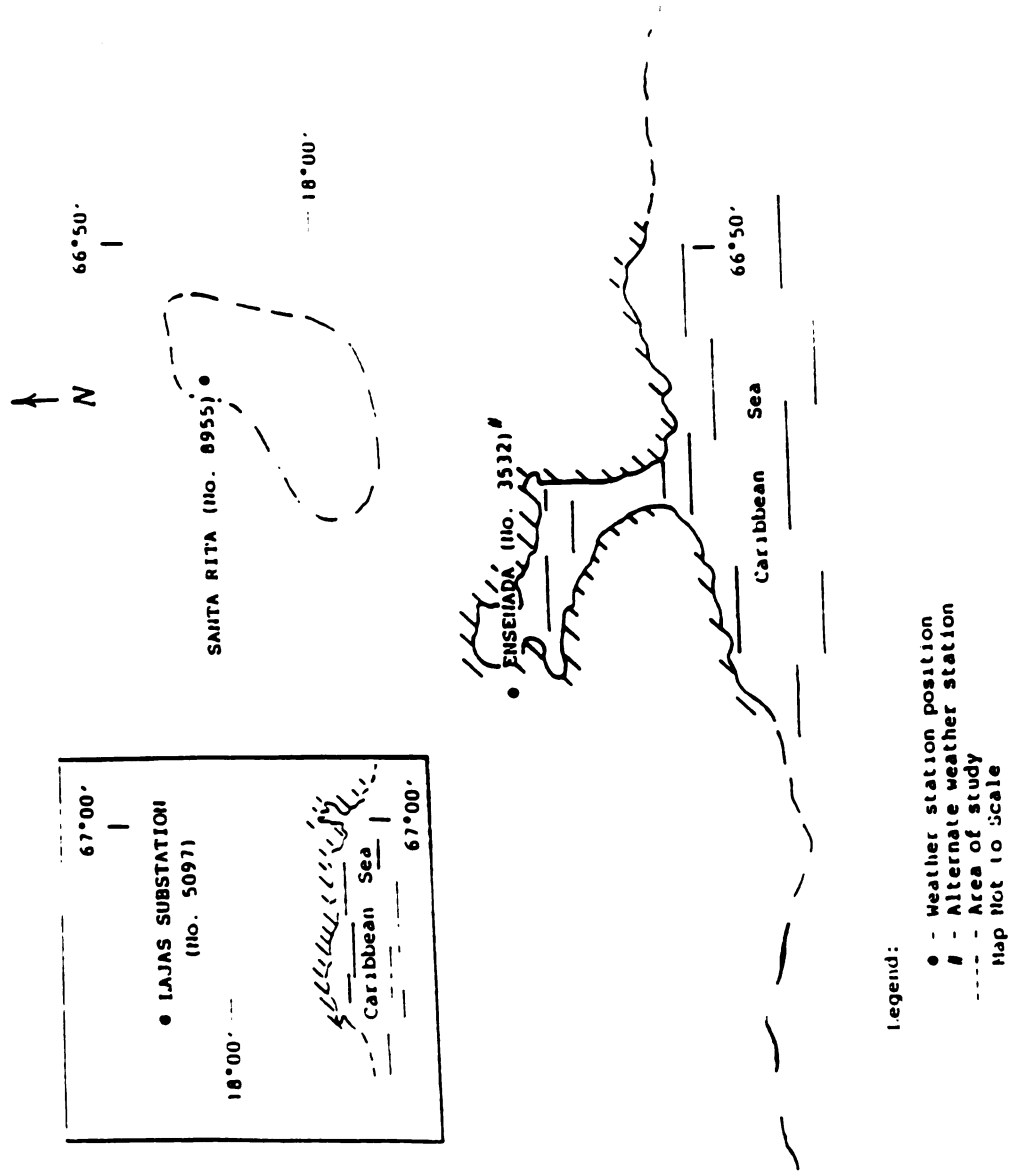


Figure 19. Guanica Valley vegetable fields location.

**(4) Tillage operations with crawler tractors on
Guanica Valley vegetable fields location.**

Usually tillage operations are performed with crawler tractors due to their size and power. The area served by ASA is bigger than the area served by the SCVP in Guanica Valley (600 ha) (See Figure 20). The service is mostly focussed to all farmers in the area including some farmers on the SCVP.

a) Soil characteristics and locations aspects. - Soils described in the Santa Isabel Valley vegetable field locations were used to describe the soils for this location.

b) Weather data. - Weather data used in the Guanica Valley vegetable fields location was used in this location.

c) Crop growing season. - Growing season assumed in the Guanica Valley vegetable fields location was assumed in this location.

**(5) Sugarcane harvesting operations performed with
combines on Santa Isabel Valley location.**

Santa Isabel Valley sugarcane production area covers approximately 1500 ha. (Leon, 1992). Some farms not devoted to the production of vegetables are devoted to sugarcane

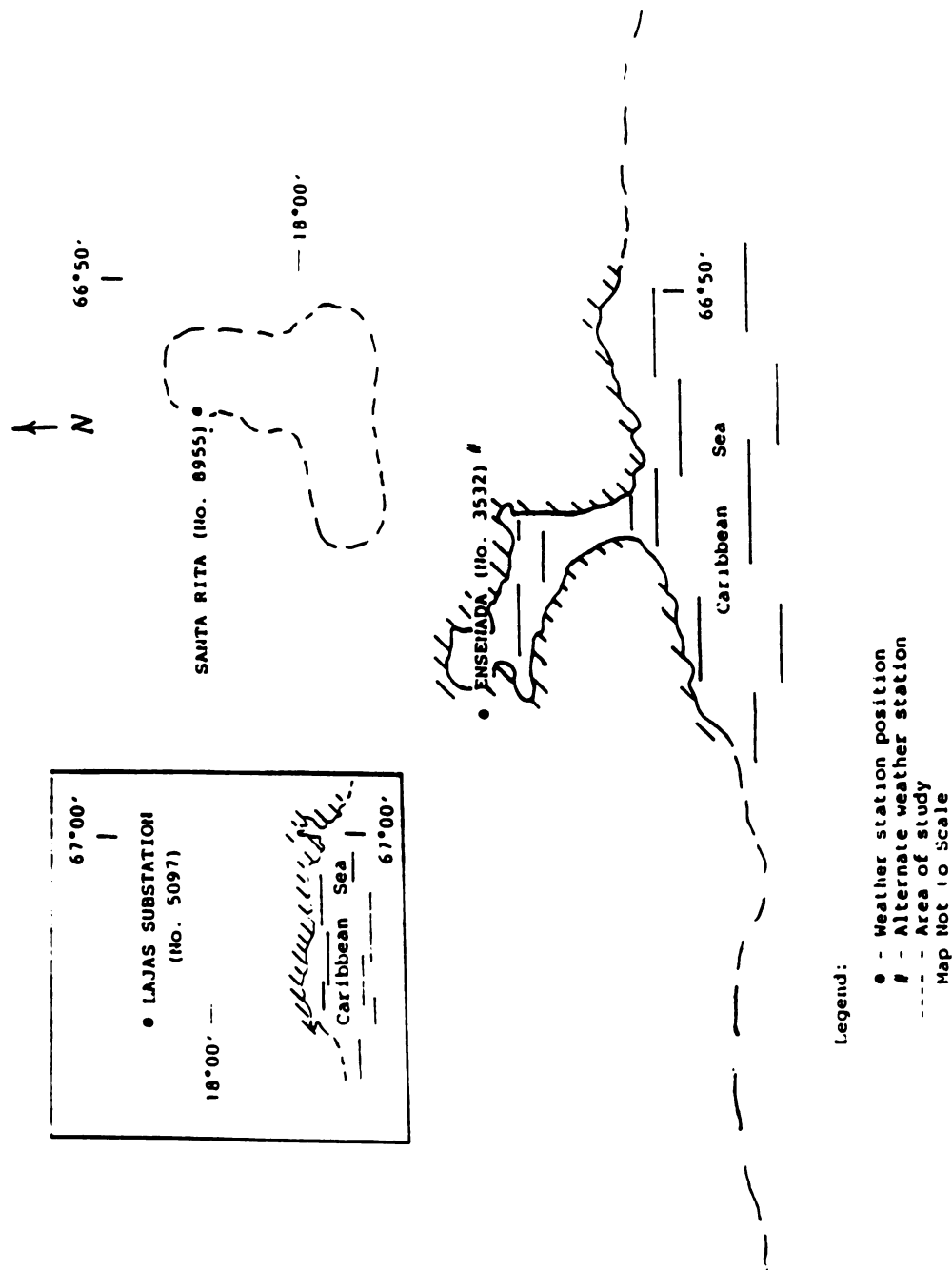


Figure 20. Guanica Valley tillage operations performed with crawler tractors on vegetable fields location.

production (See Figure 21).

a) Soil characteristics and locations aspects. - Soils described in the Santa Isabel Valley vegetable fields location were used to describe the soils for this location.

b) Weather data. - Weather data used in the Santa Isabel Valley vegetable fields location was used in this location.

c) Crop growing season. - Sugarcane of one year growing season was assumed. It was assumed that sugarcane was planted on May and June and harvested on March and April. Kc's for sugarcane (Goyal and Gonzalez, 1989b) are presented in Table 12.

e. Field operations observed data collection.

- (1) **Tillage and non-tillage operations on Santa Isabel Valley vegetable field locations,**
- (2) **Tillage and non-tillage operations on Santa Isabel Valley tomato field locations, and**
- (3) **Tillage and non-tillage operations on Guanica Valley vegetable field locations.**

Observed data for these locations were obtained from the SCVP main offices located in Santa Isabel valley during the summer of 1992. This office serves Santa Isabel and

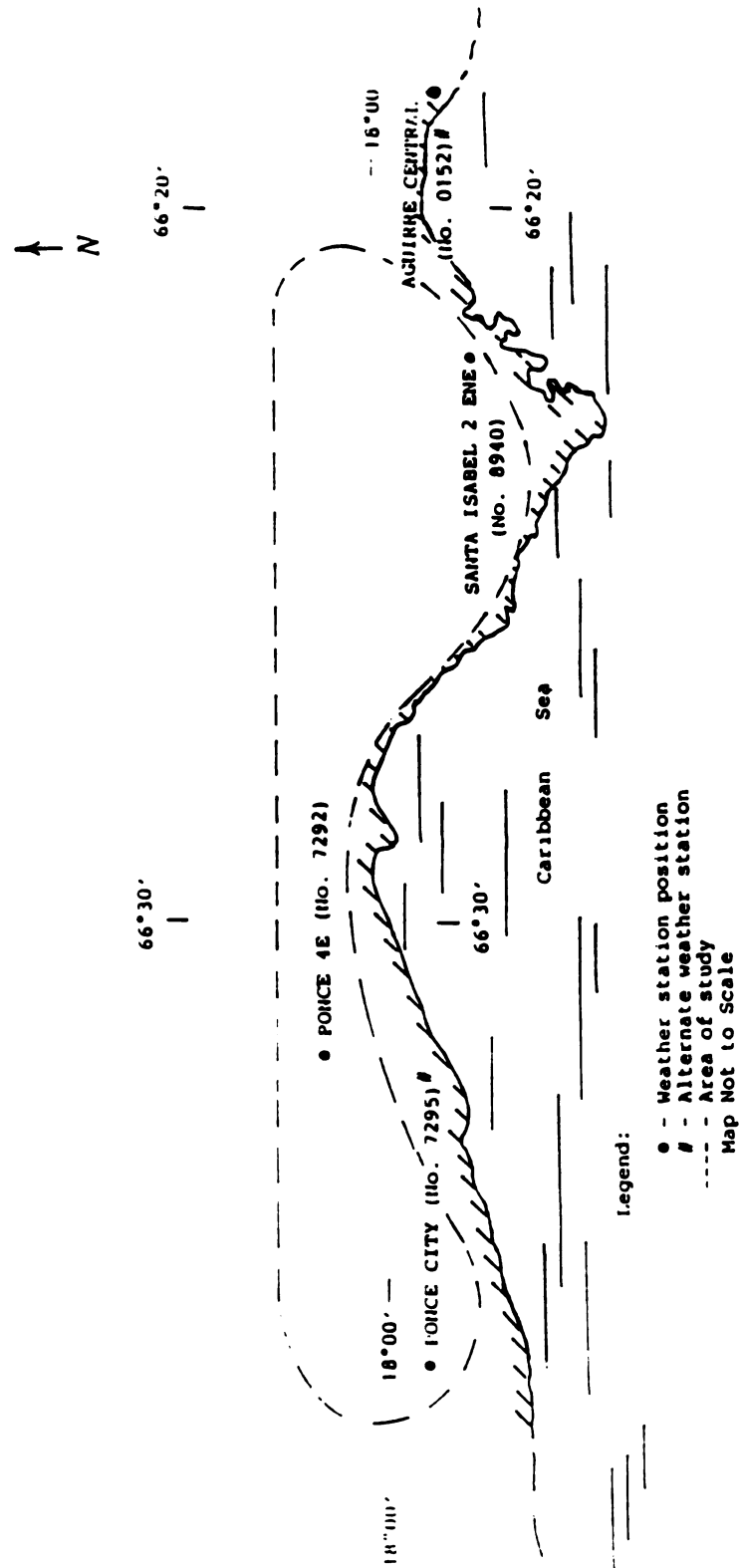


Figure 21. Santa Isabel Valley sugarcane harvesting operations performed with combines location.

Guanica valleys vegetable programs. The observed data were obtained from the weekly report "Informe de Servicio de Maquinaria Agricola"² (See Figure C.1) (Land Authority, 1992). This report is used to count the number of farmers served during the week and the number of hours that the machinery has been used on their farms.

A daily report of the number of farms that received the services, type of operation performed, and hours of operation are data obtained for July, 1989 to February, 1992 period (32 months) for Santa Isabel Valley vegetable field locations (See Table D.1). Guanica Valley vegetable field locations used 30 months of observed working days data (July 1989 to December, 1991) (See Table D.2). For Santa Isabel Valley tomato field locations three periods were obtained: from September 1989 to April 1990 (8 months), from August 1990 to May 1991 (10 months), and from August 1991 to February 1992 (5 months) for a total of 23 months (See Table D.3).

Tillage operations included operations that are normally affected by the soil moisture condition such as plowing, disking, banking, use of rotary tillers, plastic layouts, and transplanting operations. Non-tillage operations included use of service and harvesting carts, fertilizer broadcasting, and chemical aspersion. Because the majority of the vegetable in the SCVP use plastic mulch (Santiago,

² Agricultural Machinery Service Report

1992), tillage operations like cultivation, were assumed not to be performed during the growing season and were not taken into account.

These data were summed and daily tabulated in two major observations: total machinery hours worked per day and total number of operations performed per day for each operation and location.

Tillage and non-tillage operations were assumed to be performed during May to September and from October to April respectively for vegetable fields locations on Santa Isabel and Guanica valleys. In Santa Isabel Valley tomato location tillage and non-tillage operations were assumed to be effected during August to September and from October to April, respectively.

Data were analyzed in order to identify the working and non-working days for each operation category. It was found from the data of Santa Isabel and Guanica valleys vegetable field locations that during June to August (major vegetables off-season), the total operations per day and total hours per day showed an irregular trend compared with the on season month. This was mainly because of holidays, machinery operators' vacation, and normal machinery maintenance done during this period. These three months were analyzed separately.

Eight means were calculated for these two locations.
In summary:

1. total tillage hours/day for on-season
2. total tillage hours/day for off-season
3. total tillage operations/day for on-season
4. total tillage operations/day for off-season
5. total non-tillage hours/day for on-season
6. total non-tillage hours/day for off-season
7. total non-tillage operations/day for on-season
8. total non-tillage operations/day for off-season

For the Santa Isabel Valley tomato field locations four means were computed because the data obtained corresponded to on-season:

1. total tillage hours/day
2. total tillage operations/day
3. total non-tillage hours/day
4. total non-tillage operations/day

A non-working day was assumed for all the locations when:

any observed daily total was less than 33 percent of the computed mean for any of the two observations (total hours/day and total operations/day) for tillage and non-tillage operations.

Some daily values were rejected as observed data. Days reported and assumed in the previous method as non working

days when daily rainfall was less than 10 mm during that day or two previous days were not considered in the validation process. Causes not related with weather factors such as meetings, off-season period, broken machinery, etc. could be reasons why a non working day was reported.

Holidays and weekends were not considered in the analysis of observed working days. Also, some days near important holidays, days at the beginning or end of growing season were not taken into consideration.

(4) Tillage operations performed with crawler tractors on Guanica Valley vegetable field locations.

Information used as observed working days data was acquired from the machinery program of the Administration of Agricultural Services (ASA) located in the town of Guanica during the summer of 1992. This office serves the southwestern region of Puerto Rico. Observed working days data was obtained from the "Resumen de Uso de Horas de Operadores"³ (ASA, 1990-1992) weekly report for the period of January, 1990 to June, 1992 (See Figure C.2). This report shows when and where the operator was working, productive machinery hours, waiting hours, and missed hours or days due to high moisture content in the soil (reported

³Summary of Operators used hours

under column "LLUVIA"⁴). Only vegetable farms located within the area were selected.

The data were collected by adding all the hours or days reported as missed due to rainfall (See Table D.4). An observed day was declared a non working day when:

1. any day with more than 4 missed hours was reported,
or
2. any day reported at least by one operator as a missed day.

It was assumed here that at least one crawler tractor is always available to serve in the valley due to the high demand for the tractors in the area (Acevedo, 1992). During vegetable growing season, more than one tractor should be accessible in the valley. Holidays and weekends were not included in the observed data evaluation.

(5) Sugarcane harvesting operations performed with combines on Santa Isabel Valley location.

Observed data were obtained from the "Informe Semanal de Produccion de Cosechadoras Claas"⁵ for Santa Isabel Valley (Land Authority, 1988-1992). This report included a

⁴rainfall

⁵Claas Combines Weekly Production Report

weekly information of numbers of working days and non working days and why they did not worked. Holidays and weekends were also not included in the observed data evaluation. The data obtained for this location did not present working days affected by weather conditions thus were not included in this thesis.

f. Models validation process.

The validity of the three models was assessed by the precision with which they could be fitted on a day-to-day basis to the observed data of field working days for all the locations. Accuracy was measured by the percent of the days in the month that the decisions made by the simulation programs agreed with the decisions based on daily observed field operation data.

Another validity process was performed after the models achieved the highest minimum accuracy per month and the highest accuracy average per location. Comparison between total predicted and total observed working days on a monthly basis for each location and field operation using linear regression was performed. Fitting was done by adjusting the computer programs parameters for the computation of SMC (RNC, DRN, and DFF) and the definition of a working day (T , TN , T_1 , and TN_1). The models were run without changing any FC and WP. Values for FC and WP were not changed after comparing soils information contained in the soil surveys (Carter, 1961; Gierbolini, 1979).

3. Sensitivity analysis of the models.

Sensitivity tests were conducted with all the models to observe which parameter may affect the working days predictions the most. The parameters that showed a great effect in the model outputs should be used with precision. The first test (SMC criterion test) was conducted to determine the models' responses to the variation in the SMC criterion in the computation of workings days for different field operations. RNC, DRN, and DFF were assumed as 1 in all the cases. Weather data (22 months) and soil parameters for Santa Isabel Valley tomato fields location were used.

The models were also tested for their sensitivity to the runoff coefficient (RNC), drainage coefficient (DRN), and diffusion coefficient (DFF) in the computation of SMC (Soil Parameters test). Increasing RNC decreased runoff and then the SMC increased. Lowering DRN decreased the amount of drained water during the day when it is above FC then the SMC is high. When DFF increased, diffusion of water decreased raising the SMC.

Because the variation of SMC was the same in all the weather data only three months (June, July, and August of 1990) were arbitrarily selected. Number of days with SMC equal to or above FC were summed to show how these parameters affected the computation of field working days. Daily SMC mean in the 150 mm soil profile for every month was calculated to present how the soil parameters affected

the SMC computations. Total monthly runoff was computed to show how the variations in the soil parameters affected the infiltration of water into the soil.

4. PWD tables computation.

PWD tables were computed using the modified model that best predicted the working days. Sixteen years of weather data obtained from NOAA (1977-1992) was utilized. The soil parameters and field operations working days criteria used in the PWD computations were the same that better defined each location.

After the model defined the day n as a working or non-working day, a series of working days for the specific field operations was summed for the selected months. Twelve temporary files (one for each month) were created to save the total of working days per month for the sixteen years. Data on these temporary files were sorted (in descending order) using subroutine SortSI2N and saved in another 24 temporary files (two field operation files per month).

After the working days per month were sorted, the computer program added the highest eight, the first twelve, and the first fifteen working day months out of sixteen months to compute the PWD's for 0.50, 0.75, and 0.94 probability levels, respectively. PWD was computed dividing the added numbers of working days by the total of calendar days per month in eight and twelve years, respectively.

IV. RESULTS AND DISCUSSION

The results show great precision in the prediction of working days, especially for non-tillage operations. A marked difference can be observed between the model that computed SMC for only one layer of 150 mm thick and the models that computed SMC on a basis of multiple layers. Two results were evaluated (See section III.B.2.f) in order to validate the models:

1. Agreement of the prediction of working and non-working days on a daily basis.
2. Agreement of the prediction of working days on a monthly basis.

The validity of the models modified and used for this thesis depends on several assumptions and on the criteria as specified by the soil moisture content (SMC) computation and by the definition of a working day. Runoff coefficient (RNC), diffusion coefficient (DFF), and drainage coefficients (DRN) were not absolute parameters and cannot be used to identify a specific soil. These were used only to fit the predicted data with the observed working days data.

A. Validation of Models.

The tillage operation working day criteria seem slightly higher than the values recommended by Hunt (1986) and others reported by various authors (Selirio and Brown, 1972; Elliot et al., 1977). The criterion used in the definition of field working days is a parameter influenced by the SMC computation and the observed working days data. The rapid SMC depletion in a daily fashion using high ET calculations or low water infiltration (e.g. increasing runoff) may decrease the operations criterion compared with a low SMC depletion or high infiltration of water.

Some limitations were found during the validation of the models:

1. Subjectivity in the definition of which day constituted a working or non-working day in the observed data could affect the performance of the models.
2. The observed working data do not include holidays and weekends. This source of error made a gap in the continuity of a working days sequence so that when the working days predicted by the models were compared with the field data the accuracy was reduced.
3. Total hours of operations were reported in the

daily observed data. There is a possibility of counting half days as full working days. The models do not simulate half working days.

4. The use of rainfall data from an alternate weather station when rainfall data was missed.
5. Rainfall data are usually collected and reported every day at 7:00 a. m. The exact time of day it rained is not reported making it questionable whether the observed data for that day were really affected by the rainfall.

The allowable error was decided as a minimum monthly accuracy of 70% and total accuracy of 85%. This is because some of the models predicted working days when the rainfall during any day was less than 5 mm and the observed data did not reported a non working day. A correlation coefficient (R^2) of .800 was permissible because the number of observation per location was less than 20.

Tables of the validation results, monthly rainfall, number of days per month on which there was a disagreement with the observed data, observed and predicted working days per month are presented. These tables show the validity of each model tested under different sites and weather conditions. Relationships between the observed and predicted working days per month are graphically shown.

Each graph presents the efficiency in the prediction of working days for each model.

1. Observed data evaluation.

Observed working days data for Santa Isabel Valley vegetable fields, Santa Isabel Valley tomato fields, and Guanica Valley vegetable field locations were assumed to be affected by weather conditions indirectly. Non-tillage operations for Guanica Valley vegetable fields location observed data were the most difficult to predict for each model. Daily working hours reported for this location were inconsistent due to the low field area served by the South Coast Vegetable Program (SCVP). In some cases only one operation per day was reported in the entire area although the crop was in-season and no rainfall was reported for that day or the previous days.

Tillage operations using Guanica Valley vegetable fields performed with crawler tractors location data were the only observed data influenced by rainfall. The achievement of each model was observed in this location.

Sugarcane harvest operation data for Santa Isabel Valley location did not show any day affected by weather conditions during the three harvest seasons even when daily rainfall was greater than 25.4 mm (1 in.). During the analysis of the observed data for this specific location, a coincidence of rainfall greater than 25.4 mm with holidays

and weekends was found. Models' parameters for this location were assumed considering the parameters found to describe better this region for non-tillage operations on the Santa Isabel Valley vegetable fields location. No validation was done due to the lack of proper observed data.

2. Missed weather data and its effect in the validation of the models.

Five months of rainfall weather data were missed for Santa Isabel 2 Ene (No. 8940): August 1990, November 1990, January 1991, March 1991, and June 1991. Weather data from Aguirre Central (No. 0152) was used in substitution of the missed data. Two months were missed in Santa Rita (No. 8955) weather station: January 1990 and April 1991. Ensenada (No. 3532) weather station data replaced this missed data. The effect was observed when the missed data corresponded to rainy season months. Prediction of tillage and non-tillage operations for Santa Isabel Valley tomato fields location were the most affected using alternate rainfall data. The low accuracy per month obtained using modified Hunt (1986) and Tulu et al. (1974) models for these locations is due to the missed rainfall data. It seems that the use of rainfall data far from the experimental location caused negative results.

3. Modified Hunt (1986) model validation.

Tables 13 and 14 present the results for the validation of this model. The comparisons between the observed and predicted working days for tillage and non-tillage operations for each location are presented in Figures 22 to 28. Results for the prediction accuracy on a day-to-day basis and the prediction of working days in monthly basis are presented in Tables 15 to 21. These tables present in the fourth and fifth columns the number of working days observed during each month and the prediction of working days made by the model, respectively, using the soil parameters presented in Tables 13 and 14. The fifth and sixth columns represents the number of working and non-working days observed during each month and the number of times that there was a disagreement made by the output model. Same format is followed in the other models results.

This model was very precise in the prediction of working days for all of the field operations in each location (minimum $R^2 = 0.821$, minimum monthly accuracy 77.3%). The SMC computation for a 150 mm layer allowed more water to enter into the soil profile because the AWC was relatively high (20 mm). To reach FC the model required a significant rainfall (e.g. 15 mm). In other words the predicted working days simulated by this model were not affected by low rainfalls as much as the observed field operations data indicate.

Table 13. Modified Hunt (1986) model validation results predicting tillage operations.

Location	Parameters		R ²	Accuracy	
	RNC†	T\$ (%)		Total (%)	Month Minimum (%)
Santa Isabel Valley vegetable fields	0.7	95	0.907	91.5	77.8
Santa Isabel Valley tomato fields	0.7	94	0.933	87.5	83.3
Guanica Valley vegetable fields	0.5	93	0.938	90.3	78.9
Guanica Valley vegetable fields using crawler tractors	0.5	96	0.913	94.7	90.0

Legend:

† = Runoff coefficient.

\$ = Tillage field operation criteria.

Table 14. Modified Hunt (1986) model validation results predicting non-tillage operations.

Location	Parameters		R ²	Accuracy	
	RNC [†]	TN [‡] (%)		Total (%)	Month Minimum (%)
Santa Isabel Valley vegetable fields	0.7	99	0.916	95.7	81.3
Santa Isabel Valley tomato fields	0.7	97	0.966	96.2	81.2
Guanica Valley vegetable fields	0.5	98	0.821	93.2	77.3
Santa Isabel Valley sugarcane harvest	0.7	99	*	*	*

Legend:

- † - Runoff coefficient.
- ‡ - Non-tillage field operation criteria.
- # - parameters hypothesized.
- * - no validation performed.

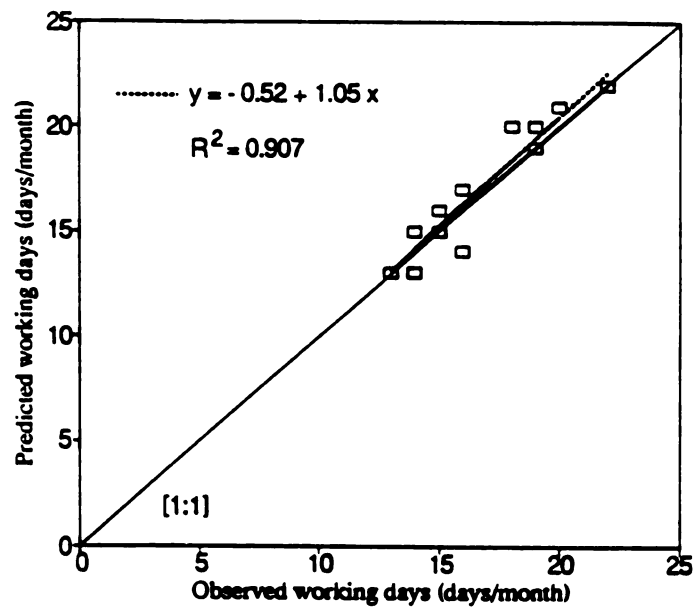


Figure 22. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Hunt (1986) model.

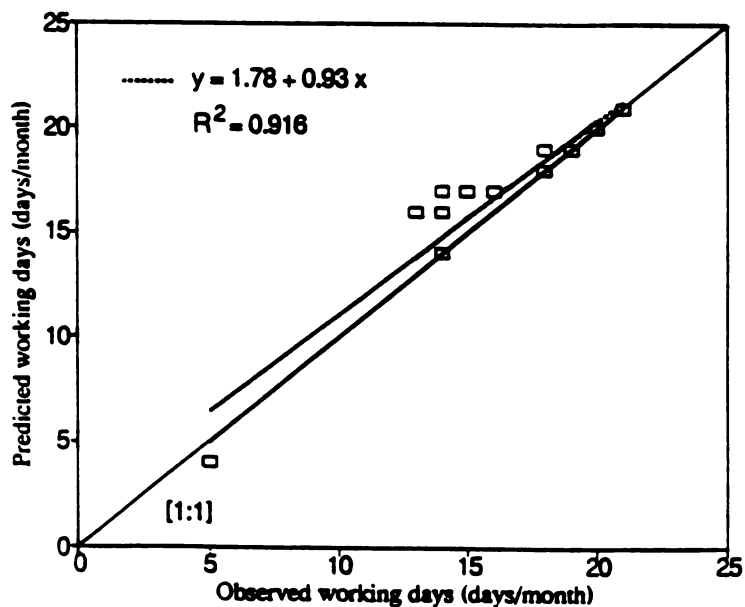


Figure 23. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Santa Isabel Valley location using modified Hunt (1986) model.

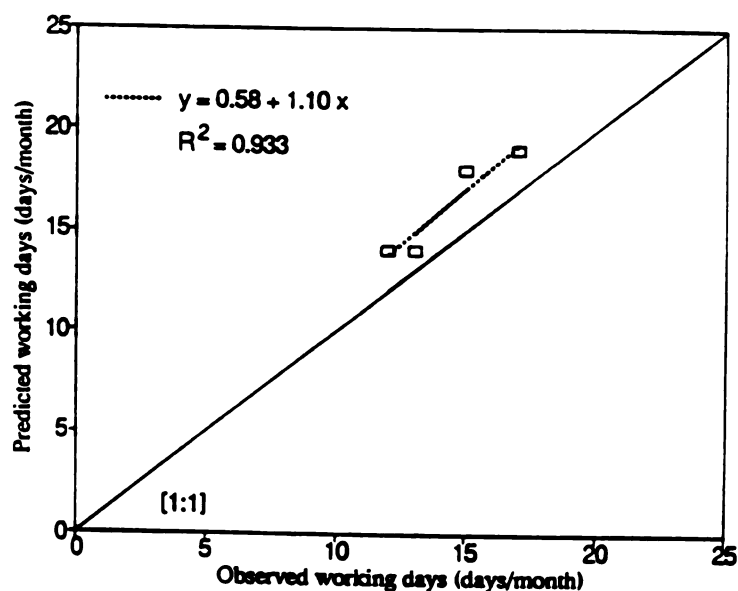


Figure 24. Comparison of the observed and predicted working days for tillage operations on tomato fields at the Santa Isabel Valley location using modified Hunt (1986) model.

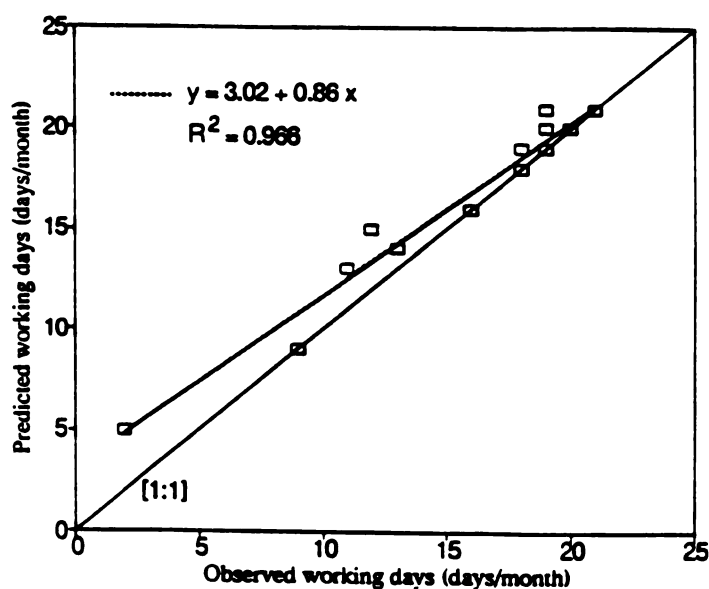


Figure 25. Comparison of the observed and predicted working days for non-tillage operations on tomato fields at the Santa Isabel Valley location using modified Hunt (1986) model.

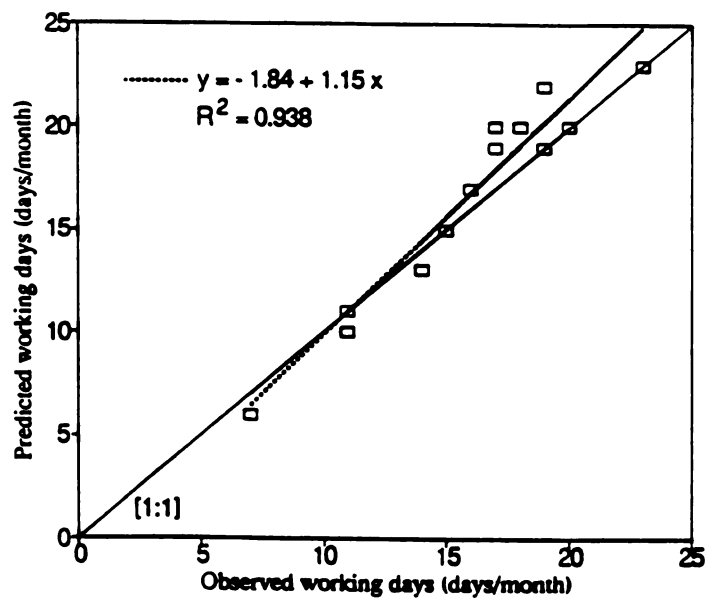


Figure 26. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.

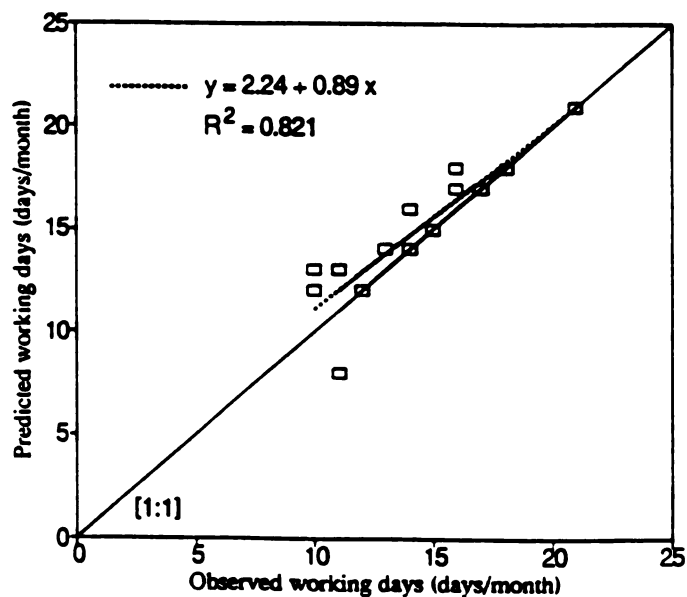


Figure 27. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.

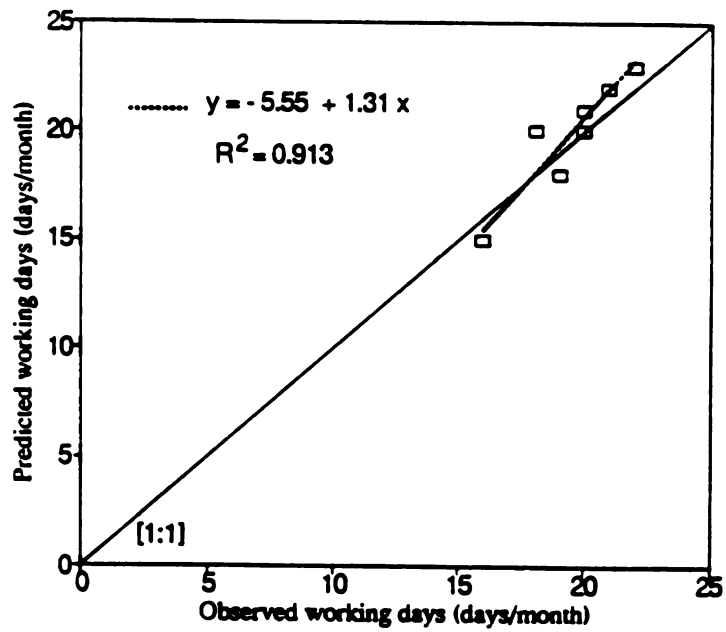


Figure 28. Comparison of the observed and predicted working days for tillage operations performed with crawler tractors on vegetable fields at the Guanica Valley location using modified Hunt (1986) model.

Table 15. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley vegetable field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Output Disagreement Percent Correct (%)
1989	Jul	30.3	16	17	17	1 94.1
	Aug	147.6	16	14	23	4 82.6
	Sep	182.7	15	15	20	4 80.0
1990	May	1.8	22	22	22	0 100.0
	Jun	72.7	15	16	20	1 95.0
	Jul	71.2	13	13	18	4 77.8
1991	Aug	58.9	22	22	22	2 90.9
	Sep	99.1	19	19	20	0 100.0
	May	47.5	20	21	19	1 94.7
	Jun	39.5	19	20	21	1 95.2
	Jul	110.2	14	13	17	1 94.1
	Aug	74.8	18	20	19	2 89.5
	Sep	62.4	14	15	20	1 95.0

(Table continued next page)

Table 15. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
(mm/mon.)						
Total		998.7	223	227	258	91.5
Regression output between observed and predicted working days:						
Constant			-0.52			
Std Err of Y Estimate			1.066			
R Squared			0.907			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			1.05			
Std Error of coefficient			0.10			

Table 16. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley vegetable field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	45.5	20	20	20	0	100.0
	Nov	12.0	20	20	20	0	100.0
	Dec	8.1	20	20	20	0	100.0
	Jan	15.9	20	20	20	0	100.0
1990	Feb	6.3	19	19	19	0	100.0
	Mar	6.5	21	21	21	0	100.0
	Apr	39.0	16	17	17	1	94.1
	Oct	449.9	5	4	22	3	86.4
1991	Nov	28.3	14	16	17	2	88.2
	Dec	16.8	18	18	18	0	100.0
	Jan	8.0	18	18	18	0	100.0
	Feb	34.8	19	19	19	0	100.0
	Mar	63.4	15	17	17	2	88.2
	Apr	9.5	14	14	14	0	100.0
	Oct	35.5	18	19	19	1	94.7
	Nov	91.0	14	17	17	3	82.4
	Dec	6.2	20	20	20	0	100.0

(Table continued next page)

Table 16. (cont'd).

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1992	Jan	180.3	13	16	16	3	81.3
	Feb	16.0	19	19	19	0	100.0
Total		1073.0	323	334	353	15	95.8
Regression output between predicted and observed working days:							
Constant			1.78				
Std Err of Y Estimate			1.119				
R Squared			0.916				
No. of Observations			19				
Degrees of Freedom			17				
X Coefficient			0.929				
Std Error of coefficient			0.068				

Table 17. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley tomato field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Jul	160.0	13	14	20	3	85.0
1990	Aug	33.1	15	18	18	3	83.3
	Sep	79.9	17	19	19	2	89.5
1991	Aug	81.2	17	19	20	2	90.0
	Sep	67.3	12	14	19	2	89.5
Total			74	84	96	12	87.5
Regression output between predicted and observed working days:							
Constant			0.58				
Std Err of Y Estimate			0.776				
R Squared			0.933				
No. of Observations			5				
Degrees of Freedom			3				
X Coefficient			1.10				
Std Error of coefficient			0.221				

Table 18. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley tomato field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	15.3	11	13	13	2	84.6
	Nov	0.0	16	16	16	0	100.0
	Dec	16.0	19	19	19	0	100.0
	Jan	12.2	19	21	21	2	90.5
1990	Feb	3.8	19	19	19	0	100.0
	Mar	1.3	19	19	19	0	100.0
	Apr	26.2	9	9	9	0	100.0
	Oct	393.2	2	5	22	3	86.4
1991	Nov	16.5	12	15	16	3	81.3
	Dec	33.0	18	18	18	0	100.0
	Jan	6.0	20	20	20	0	100.0
	Feb	25.4	19	19	19	0	100.0
	Mar	72.2	18	18	18	0	100.0
	Apr	0.0	21	21	21	0	100.0
	Oct	24.2	18	19	19	1	94.7
	Nov	97.8	13	14	16	1	93.8
	Dec	6.3	21	21	21	0	100.0

(Table continued next page)

Table 18. (cont'd).

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1992	Jan	134.6	19	20	20	1	95.0
	Feb	15.2	19	19	19	0	100.0
Total			312	325	345	13	96.2
Regression output between predicted and observed working days:							
Constant			3.02				
Std Err of Y Estimate			0.818				
R Squared			0.966				
No. of Observations			19				
Degrees of Freedom			17				
X Coefficient			0.86				
Std Error of coefficient			0.039				

Table 19. Results in the prediction of working days and output agreement for tillage operations on Guanica Valley vegetable field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Jul	11.2	11	11	11	0	100.0
	Aug	59.9	17	19	20	4	80.0
	Sep	262.0	7	6	19	3	84.2
1990	May	14.4	18	20	20	2	90.0
	Jun	134.0	14	13	17	1	94.1
	Jul	125.0	11	10	17	3	82.4
	Aug	62.5	23	23	23	0	100.0
	Sep	193.0	15	15	19	4	78.9
1991	May	59.6	20	20	20	0	100.0
	Jun	7.1	19	19	19	0	100.0
	Jul	55.2	17	20	20	3	85.0
	Aug	82.6	19	22	22	3	86.4
	Sep	64.2	16	17	19	1	94.7

(Table continued next page)

Table 19. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Disagreement Correct (%)
(mm/mon.)						
Total		1130.7	207	215	246	90.2
Regression output between predicted and observed working days:						
Constant			-1.84			
Std Err of Y Estimate			1.34			
R Squared			0.938			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			1.15			
Std Error of coefficient			0.089			

Table 20. Results in the prediction of working days and output agreement for non-tillage operations on Guanica Valley vegetable field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	34.5	10	13	14	3	78.6
	Nov	137.6	10	12	17	2	88.2
	Dec	0.0	12	12	12	0	100.0
1990	Jan	3.3	18	18	18	0	100.0
	Feb	2.5	18	18	18	0	100.0
	Mar	32.3	16	18	18	2	88.9
	Apr	70.3	14	16	16	2	87.5
	Oct	430.9	11	8	22	5	77.3
	Nov	65.5	15	15	16	1	93.8
	Dec	10.9	15	15	15	0	100.0
1991	Jan	0.0	17	17	17	0	100.0
	Feb	35.6	16	17	17	1	94.1
	Mar	102.0	18	18	18	0	100.0
	Apr	47.2	21	21	21	0	100.0
	Oct	53.1	14	14	14	0	100.0
	Nov	99.0	11	13	13	2	84.6
	Dec	13.2	13	14	14	1	92.9

(Table continued next page)

Table 20. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct
		(mm/mon.)				(%)
Total		1138.2	249	259	280	93.2
Regression output between predicted and observed working days:						
Constant			2.24			
Std Err of Y Estimate			1.37			
R Squared			0.821			
No. of Observations			17			
Degrees of Freedoms			15			
X Coefficient			0.89			
Std Error of coefficient			0.11			

Table 21. Results in the prediction of working days and output agreement for tillage operations performed by crawler tractors on Guanica Valley vegetable field locations using modified Hunt (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
1990	May	14.4	21	22	22	95.5
	Jun	134.0	19	18	20	90.0
	Jul	125.0	16	15	19	94.7
	Aug	62.5	22	23	23	95.7
	Sep	193.0	16	15	19	94.7
1991	May	59.6	21	22	22	95.5
	Jun	7.1	20	20	20	100.0
	Jul	55.2	20	21	21	95.2
	Aug	82.6	21	22	22	95.5
	Sep	64.2	18	20	20	90.0
Total			194	198	208	94.7
Regression output between predicted and observed working days:						
Constant			-5.55			
Std Err of Y Estimate			0.91			
R Squared			0.913			
No. of Observations			10			
Degrees of Freedom			8			
X Coefficient			1.31			
Std Error of coefficient			0.14			

Runoff coefficient (RNC) for the Santa Isabel Valley field locations (vegetable and tomato) was 0.7. For Guanica Valley vegetable locations RNC was 0.5 (See Table 13 and 14). It is significant to note that the same soil parameters used in this model seem to describe all four locations quite well. RNC near 0.5 is also common in the other models because the maximum saturation was computed for the first 150 mm of soil profile.

Tillage operations criteria (T) fluctuated from 93% to 96% of the FC (See Table 13) Non-tillage operations criteria (TN) varied from 97% to 99% (See Table 14).

4. Modified Tulu et al. (1974) model validation.

The modified Tulu et al. (1974) model was very difficult to validate for tillage operations. Tables 22 and 23 present the validation results. Figures 29 to 35 show the comparison between the observed and predicted working days. Accuracy in the prediction agreement of observed days and prediction of working days in monthly basis are presented in Tables 24 to 30.

The reason for the low predictions is that the model defined the first and the second layers as having a thickness of 30 and 45 mm respectively. AWC's in these layers were relatively low (4 and 6 mm for the first and the second layer, respectively). The first layer reached FC when daily rainfall was near 3 mm. It is known that in dry

Table 22. Modified Tulu et al. (1974) model validation results predicting tillage operations.

Location	Parameters									R ²	Accuracy	
	RNC [†]	DRN [‡]			T [§]			Total	Month Minimum			
		1 [§]	2	3	1 [§]	2	3				(%)	(%)
Santa Isabel Valley vegetable fields	0.4	1	1	1	96	97	99	0.682	85.7	68.4		
Santa Isabel Valley tomato fields	0.7	1	1	1	96	97	99	0.895	81.2	72.2		
Guanica Valley vegetable fields	0.5	1	1	1	97	98	99	0.943	87.8	73.7		
Guanica Valley vegetable fields using crawler tractors	0.5	1	1	1	97	98	99	0.950	91.8	84.2		

Legend:

† = Runoff coefficient

‡ = Drainage coefficient

§ = Tillage field operation criteria for the layers

§ = Layer number

Table 23. Modified Tulu et al. (1974) model validation results predicting non-tillage operations.

Location	Parameters						R ²		Accuracy	
	RNC [†]		DRN [†]			TN ^{\$}			Total	Month Minimum
	1 ^{\$}	2	3	1 ^{\$}	2	3	(%)		(%)	(%)
Santa Isabel Valley vegetable fields	0.4	1	1	1	99	99	99	0.912	92.6	70.6
Santa Isabel Valley tomato fields	0.7	1	1	1	99	99	99	0.958	94.5	81.2
Guanica Valley vegetable fields	0.5	1	1	1	99	99	99	0.775	86.1	53.8
Santa Isabel Valley sugarcane harvest [#]	0.7	1	1	1	99	99	99	*	*	*

Legend:

- † = Runoff coefficient
- ‡ = Drainage coefficient
- \$ = Non-tillage field operation criteria for the layers
- £ = Layer number
- # - parameters hypothesized
- * - no validation performed

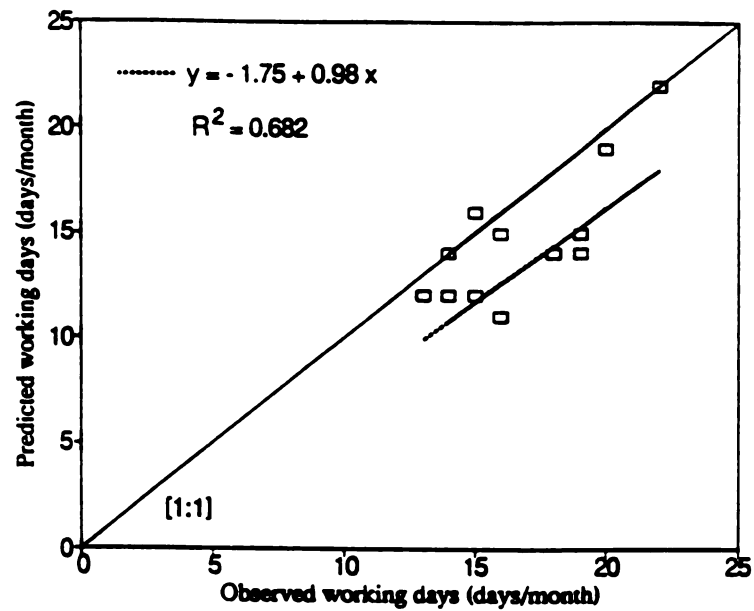


Figure 29. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Tulu et al. (1974) modified model.

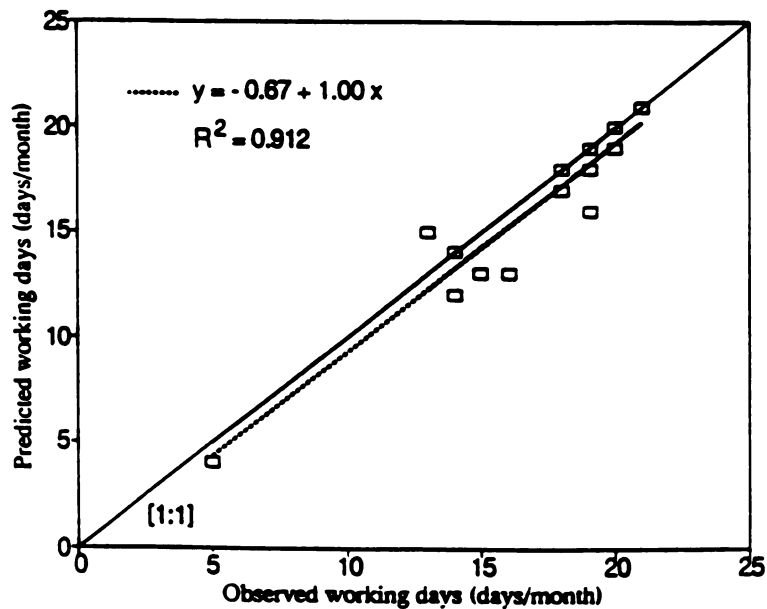


Figure 30. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.

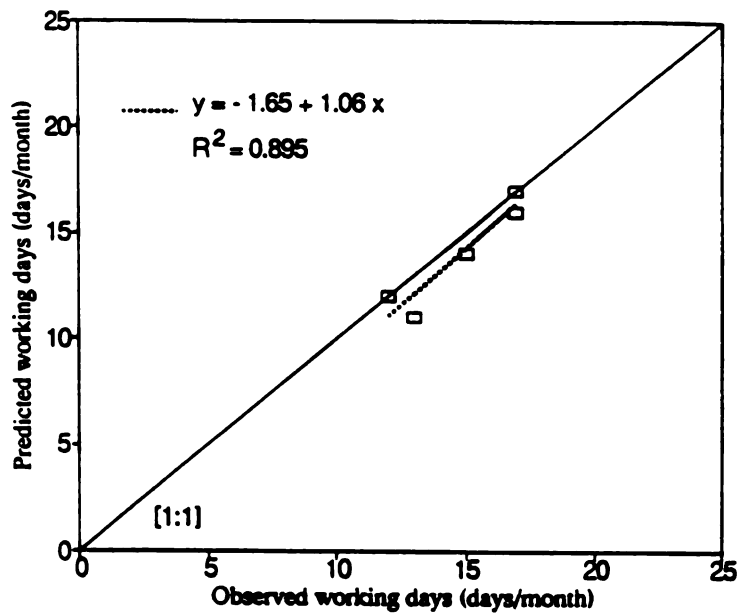


Figure 31. Comparison of the observed and predicted working days for tillage operations on tomato fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.

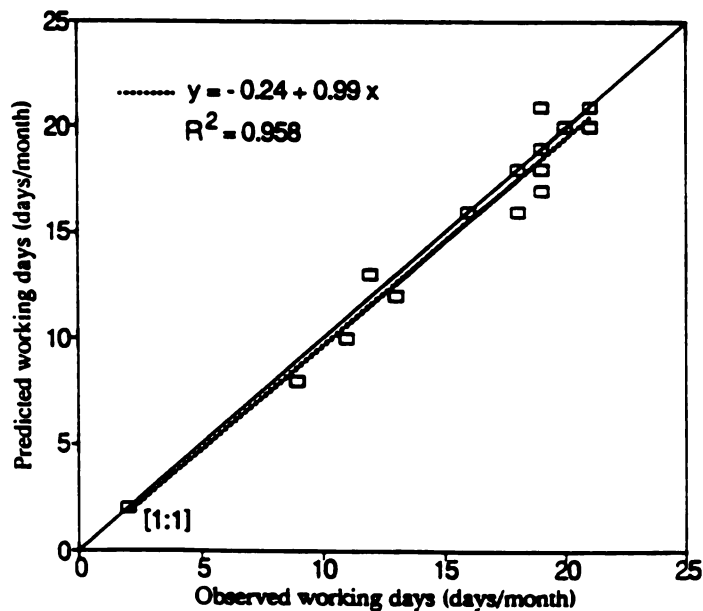


Figure 32. Comparison of the observed and predicted working days for non-tillage operations on tomato fields at the Santa Isabel Valley location using modified Tulu et al. (1974) model.

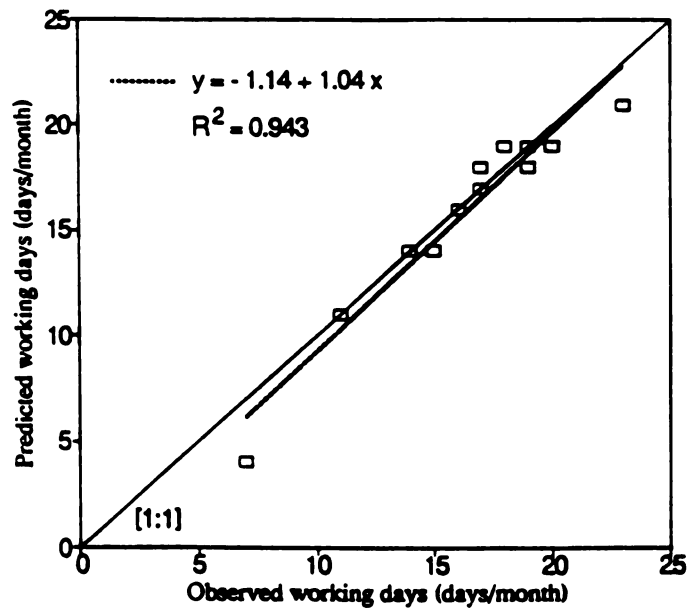


Figure 33. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Guanica Valley location using modified Tulu et al. (1974) model.

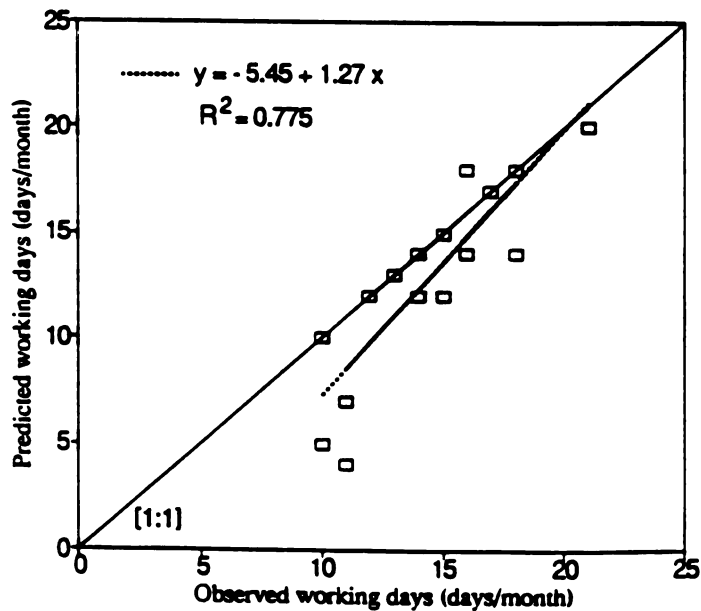


Figure 34. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Guanica Valley location using modified Tulu et al. (1974) model.

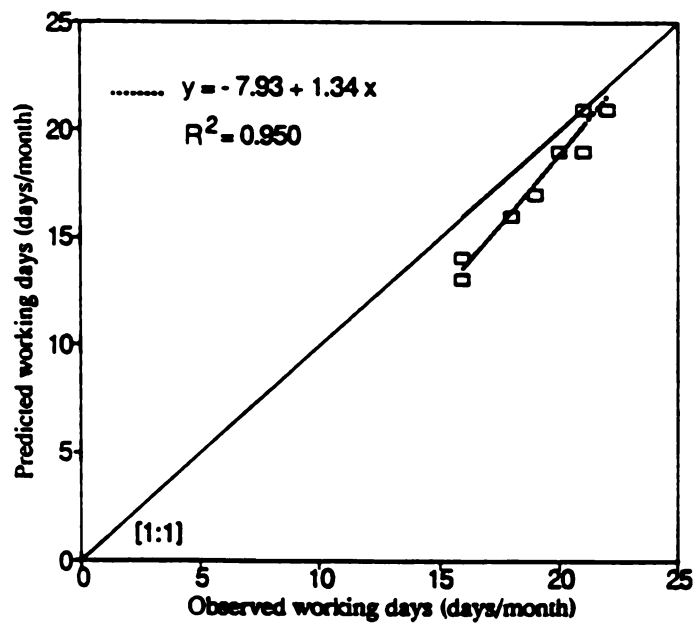


Figure 35. Comparison of the observed and predicted working days for tillage operations performed with crawler tractors in vegetable fields at the Guanica Valley location using modified Tulu et al. (1974) model.

Table 24. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley vegetable field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Jul	30.3	16	15	17	1	94.1
	Aug	147.6	16	11	23	5	78.3
	Sep	182.7	15	12	20	3	85.0
1990	May	1.8	22	22	22	0	100.0
	Jun	72.7	15	16	20	3	85.0
	Jul	71.2	13	12	18	1	94.4
1991	Aug	58.9	22	22	22	2	90.9
	Sep	99.1	19	14	20	5	75.0
	May	47.5	20	19	19	1	94.7
	Jun	39.5	19	15	21	4	81.0
	Jul	110.2	14	14	17	2	88.2
	Aug	74.8	18	14	19	6	68.4
	Sep	62.4	14	12	20	4	80.0

(Table continued next page)

Table 24. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct
		(mm/mon.)				(%)
Total		998.7	223	198	258	85.7
Regression output between predicted and observed working days:						
Constant			-1.75			
Std Err of Y Estimate			2.15			
R Squared			0.682			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			0.98			
Std Error of coefficient			0.204			

Table 25. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley vegetable field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	45.5	20	19	20	1	95.0
	Nov	12.0	20	19	20	1	95.0
	Dec	8.1	20	20	20	0	100.0
	Jan	15.9	20	19	20	1	95.0
1990	Feb	6.3	19	19	19	0	100.0
	Mar	6.5	21	21	21	0	100.0
	Apr	39.0	16	13	17	5	70.6
	Oct	49.9	5	4	22	1	95.5
1991	Nov	28.3	14	14	17	2	88.2
	Dec	16.8	18	18	18	0	100.0
	Jan	8.0	18	18	18	0	100.0
	Feb	34.8	19	16	19	3	84.2
	Mar	63.4	15	13	17	4	76.5
	Apr	9.5	14	14	14	0	100.0
	Oct	35.5	18	17	19	1	94.7
	Nov	91.0	14	12	17	2	88.2
	Dec	6.2	20	20	20	0	100.0

(Table continued next page)

Table 25. (cont'd).

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct
1992	Jan	180.3	13	15	16	75.0
	Feb	16.0	19	18	19	94.7
Total		1073.0	323	309	353	92.6
Regression output between predicted and observed working days:						
Constant			-0.67			
Std Err of Y Estimate			1.23			
R Squared			0.912			
No. of Observations			19			
Degrees of Freedom			17			
X Coefficient			1.00			
Std Error of coefficient			0.075			

Table 26. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley tomato field locations using modified Tulu et al. (1974) model.

Year	Month	Prec.	Working Days		Observed Days	
		(mm/mon.)	Observed	Predicted	Total	Percent Correct (%)
1989	Sep	160.0	13	11	20	90.0
1990	Aug	33.1	15	14	18	72.2
	Sep	79.9	17	17	19	78.9
1991	Aug	81.2	17	16	20	75.0
	Sep	67.3	12	12	19	89.5
Total		421.5	74	70	96	81.3
Regression output between predicted and observed working days:						
Constant			-1.65			
Std Err of Y Estimate			0.954			
R Squared			0.895			
No. of Observations			5			
Degrees of Freedom			3			
X Coefficient			1.06			
Std Error of coefficient			0.21			

Table 27. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley tomato field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
1989	Oct	15.3	11	10	13	92.3
	Nov	0.0	16	16	16	100.0
	Dec	16.0	19	18	19	94.7
	Jan	12.2	19	21	21	90.5
1990	Feb	3.8	19	19	19	100.0
	Mar	1.3	19	19	19	100.0
	Apr	26.2	9	8	9	88.9
	Oct	393.2	2	2	22	100.0
1991	Nov	16.5	12	13	16	81.3
	Dec	33.0	18	18	18	100.0
	Jan	6.0	20	20	20	100.0
	Feb	25.4	19	17	19	89.5
	Mar	72.2	18	16	18	88.9
	Apr	0.0	21	21	21	100.0
	Oct	24.2	18	18	19	100.0
	Nov	97.8	13	12	16	81.3
	Dec	6.3	21	20	21	95.2

(Table continued next page)

Table 27. (cont'd).

Year	Month	Prec. (mm./mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1992	Jan	134.6	19	18	20	1	95.0
	Feb	15.2	19	17	19	2	89.5
Total			312	303	345	19	94.5
Regression output between predicted and observed working days:							
Constant			-0.24				
Std Err of Y Estimate			1.047				
R Squared			0.958				
No. of Observations			19				
Degrees of Freedom			17				
X Coefficient			0.99				
Std Error of coefficient			0.05				

Table 28. Results in the prediction of working days and output agreement for tillage operations on Guanica Valley vegetable field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct
1989	Jun	11.2	11	11	11	0	100.0
	Jul	59.9	17	17	20	4	80.0
	Aug	262.7	7	4	19	3	84.2
	May	14.4	18	19	20	1	95.0
1990	Jun	134.0	14	14	17	4	76.5
	Jul	125.4	11	11	17	2	88.2
	Aug	62.5	23	21	23	2	91.3
	Sep	163.0	15	14	19	5	73.7
1991	May	59.6	20	19	20	1	95.0
	Jun	7.1	19	18	19	1	94.7
	Jul	55.2	17	18	20	5	75.0

(Table continued next page)

Table 28. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
		(mm/mon.)	Observed	Predicted	Total	Percent Correct
					Output Disagreement	(%)
	Aug	82.6	19	19	22	90.9
	Sep	64.2	16	16	19	100.0
Total		1130.7	207	201	246	87.8
Regression output between predicted and observed working days:						
Constant			-1.14			
Std Err of Y Estimate			1.161			
R Squared			0.943			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			1.04			
Std Error of coefficient			0.08			

Table 29. Results in the prediction of working days and output agreement for non-tillage operations on Guanica Valley vegetable field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	34.5	10	10	14	4	71.4
	Nov	137.6	10	5	17	5	70.6
	Dec	0.0	12	12	12	0	100.0
1990	Jan	3.3	18	18	18	0	100.0
	Feb	2.5	18	18	18	0	100.0
	Mar	32.3	16	18	18	2	88.9
	Apr	70.3	14	14	16	4	75.0
	Oct	430.9	11	4	22	7	68.2
1991	Nov	65.5	15	12	16	2	87.5
	Dec	10.9	15	15	15	0	100.0
	Jan	0.0	17	17	17	0	100.0
	Feb	35.6	16	14	17	2	88.2
	Mar	102.3	18	14	18	4	77.8
	Apr	47.2	21	20	21	1	95.2
	Oct	53.1	14	12	14	2	85.7
	Nov	99.0	11	7	13	6	53.8
	Dec	13.2	13	13	14	0	100.0

(Table continued next page)

Table 29. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
		(mm/mon.)	Observed	Predicted	Total	Percent Correct (%)
Total		1138.2	249	223	280	86.1
Regression output between predicted and observed working days:						
Constant			-5.45			
Std Err of Y Estimate			2.259			
R Squared			0.775			
No. of Observations			17			
Degrees of Freedom			15			
X Coefficient			1.27			
Std Error of coefficient			0.18			

Table 30. Results in the prediction of working days and output agreement for tillage operations performed by crawler tractors on Guanica Valley vegetable field locations using modified Tulu et al. (1974) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
1990	May	14.4	21	21	22	90.9
	Jun	134.0	19	17	20	95.0
	Jul	125.0	16	13	19	84.2
	Aug	62.5	22	21	23	95.7
	Sep	193.0	16	14	19	89.5
1991	May	59.6	21	21	22	100.0
	Jun	7.1	20	19	20	95.0
	Jul	55.2	20	19	21	85.7
	Aug	82.6	21	19	22	90.9
	Sep	64.2	18	16	20	90.0
Total		797.6	194	180	208	91.8
Regression output between predicted and observed working days:						
Constant			-7.93			
Std Err of Y Estimate			0.691			
R Squared			0.950			
No. of Observations			10			
Degrees of Freedom			8			
X Coefficient			1.34			
Std Error of coefficient			0.11			

regions this amount of rainfall does not stop any field operation (Santiago, 1992; Leon, 1992).

In order to fit the predicted working days with the observed working days for tillage operations, T_1 and T_2 should be higher (96 and 97%) (See Table 22). Drainage coefficient for the layers (DRN_i) were assumed to be 1 in all locations. This allowed the layers to drain water at their maximum capacity when the SMC was above FC in each layer (Tulu et al., 1974). Runoff coefficient (RNC) was lower in the Santa Isabel Valley vegetable fields location ($RNC = 0.4$). This resulted in a high runoff computation, decreasing infiltration of water to the soil.

In the predictions of non-tillage operations the model worked well except for the Guanica Valley vegetable field locations ($R^2 = 0.775$; minimum accuracy = 53.8%) (See Table 23).

5. Modified Babeir et al. (1986) model validation.

The modified Babeir et al. (1986) model predicted the working days with adequate accuracy (See Tables 31, 32, and 33 to 39). Figures 36 to 42 show the comparison between observed and predicted working days on a monthly basis. The reason that this model worked better than the modified Tulu et al. (1974) model is that the AWC's were relatively high in the first two layers ($AWC = 6.6$ mm). Secondly, the diffusion between layers allowed a rapid depletion of SMC,

Table 31. Modified Babeir et al. (1986) model validation results predicting tillage operations.

Location	Parameters					R ²	Accuracy	
	RNC†	DRN‡	DFF**	T§	Total		Month	
1 [£] 2 3				(%)	(%)	(%)		
Santa Isabel Valley vegetable fields	0.7	1	0.6	96 96 98	0.915	92.6	80.0	
Santa Isabel Valley tomato fields	0.7	1	0.6	92 92 92	0.877	87.5	80.0	
Guanica Valley vegetable fields	0.5	1	0.7	95 96 99	0.923	89.0	76.5	
Guanica Valley vegetable fields using crawler tractors	0.5	1	0.7	95 96 99	0.927	95.2	89.5	

Legend:

- † = Runoff coefficient.
- ‡ = Drainage coefficient.
- ** = Diffusion coefficient.
- \$ = Tillage field operation criteria for the layers.
- £ = Layer number.

Table 32. Modified Babeir et al. (1986) model validation results predicting non-tillage operations.

Location	Parameters						R ²	Accuracy	
	RNC [†]	DRN [*]	DFF ^{**}	TN [‡]				Total	Month Minimum
				1 [£]	2	3			
							(%)		
Santa Isabel Valley vegetable fields	0.7	1.0	0.6	99	99	99	0.947	96.3	76.4
Santa Isabel Valley tomato fields	0.7	1.0	0.9	98	99	99	0.955	95.7	81.3
Guanica Valley vegetable fields	0.5	0.9	0.8	99	99	99	0.855	91.8	77.3
Santa Isabel Valley sugarcane harvest [#]	0.7	1.0	0.6	99	99	99	*	*	*

Legend:

- † = Runoff coefficient.
- ‡ = Drainage coefficient.
- †† = Diffusion coefficient.
- \$ = Non-tillage field operation criteria for the layers.
- £ = Layer number.
- # = Parameters hypothesized.
- * = No validation performed.

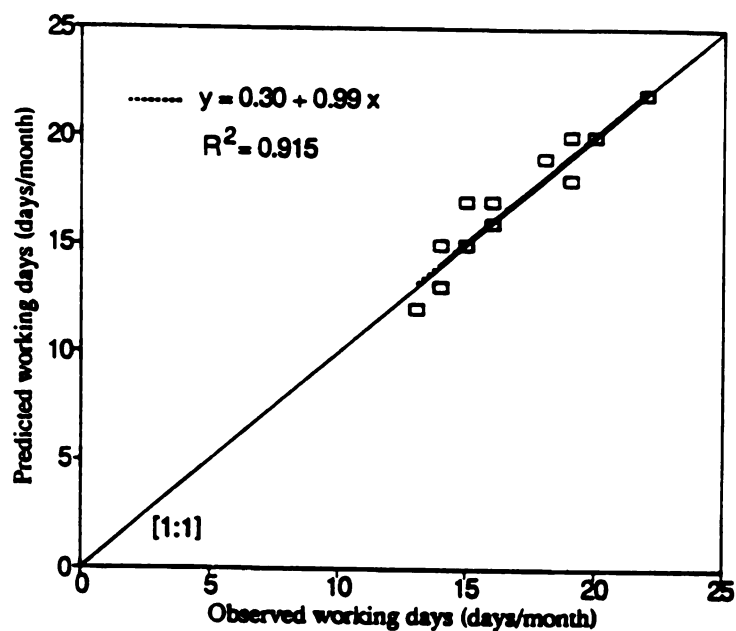


Figure 36. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Santa Isabel Valley location using modified Babeir et al. (1986) model.

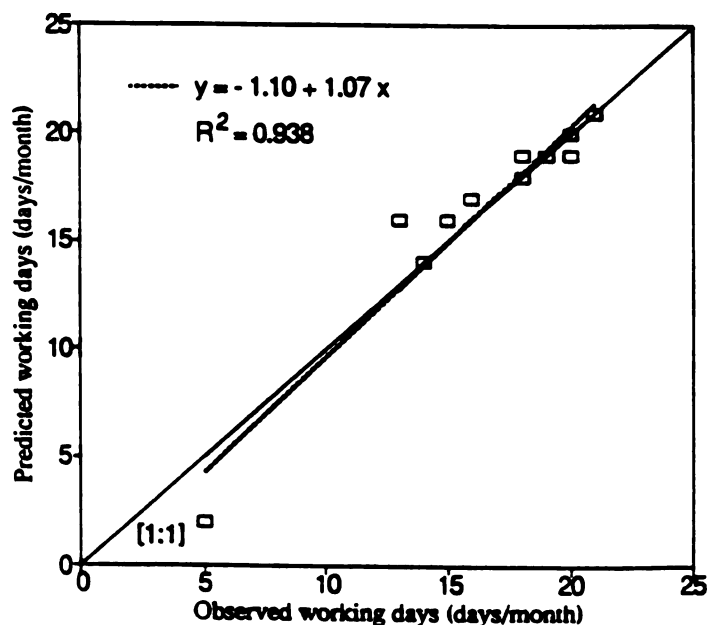


Figure 37. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Santa Isabel Valley location using modified Babeir et al. (1986) model.

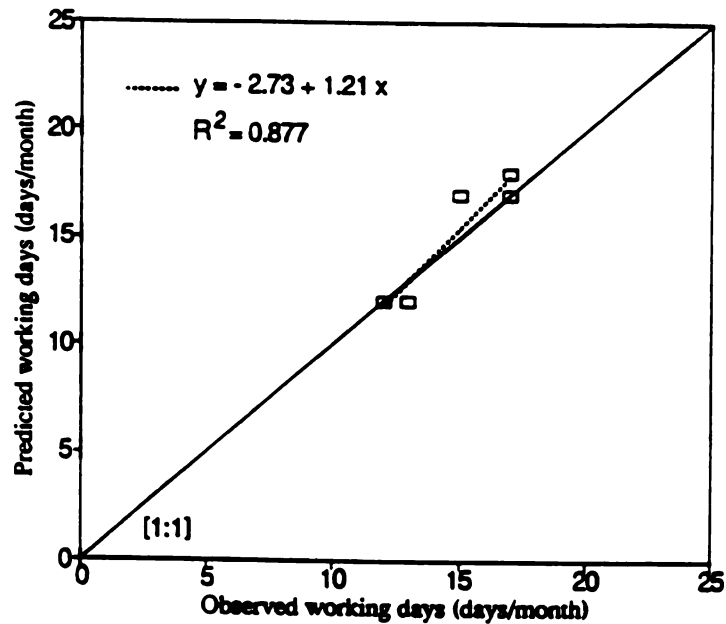


Figure 38. Comparison of the observed and predicted working days for tillage operations on tomato fields at the Santa Isabel Valley location using modified Babeir et al. (1986) model.

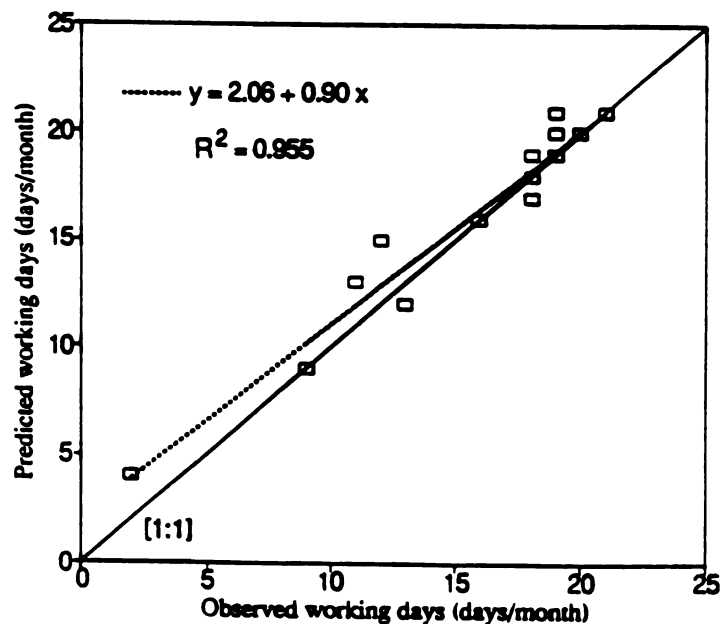


Figure 39. Comparison of the observed and predicted working days for non-tillage operations on tomato fields at the Santa Isabel Valley location using modified Babeir et al. (1986) model.

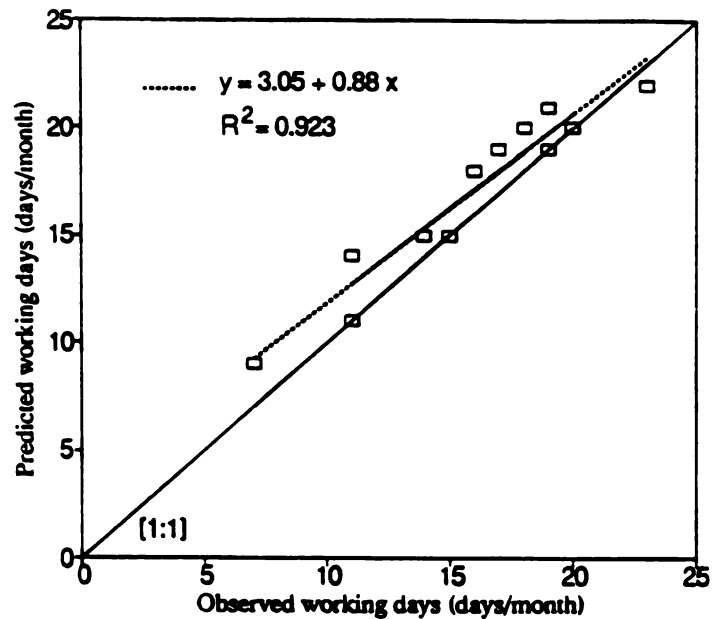


Figure 40. Comparison of the observed and predicted working days for tillage operations on vegetable fields at the Guanica Valley location using modified Babeir et al. (1986) model.

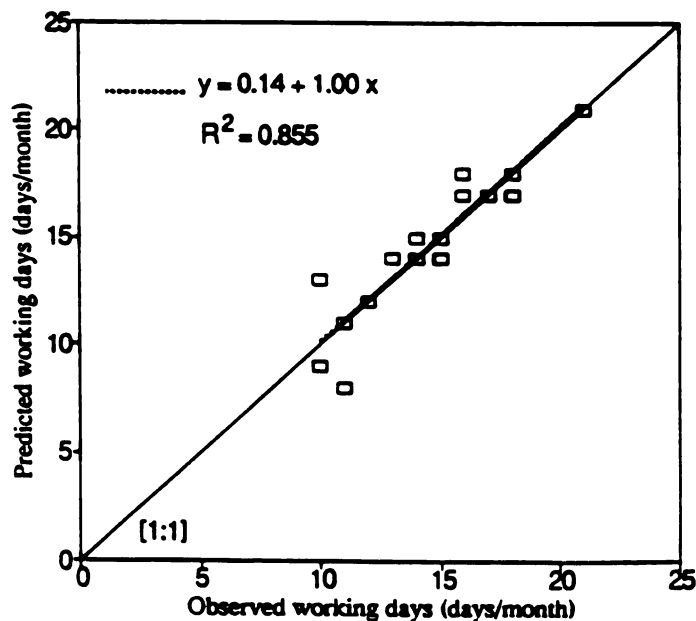


Figure 41. Comparison of the observed and predicted working days for non-tillage operations on vegetable fields at the Guanica Valley location using modified Babeir et al. (1986) model.

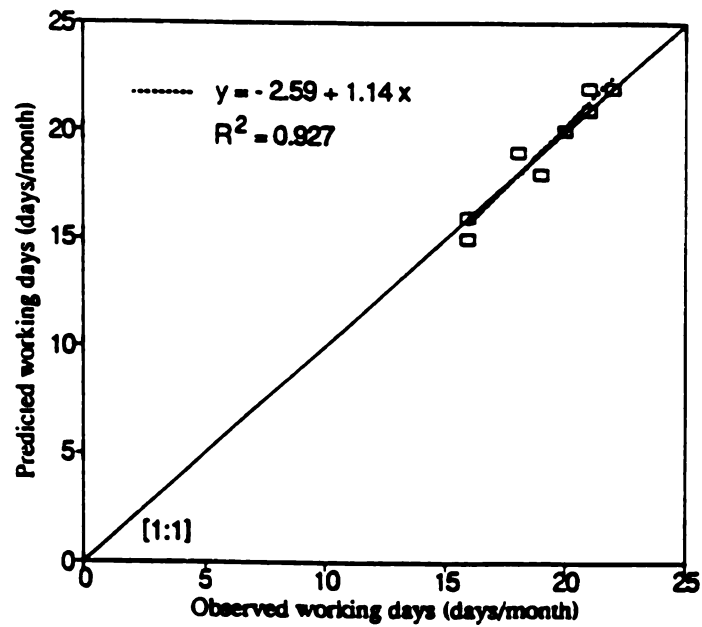


Figure 42. Comparison of the observed and predicted working days for tillage operations performed with crawlers tractors on vegetable fields at the Guanica Valley location using modified Babeir et al. (1986) model.

Table 33. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley vegetable field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
1989	Jul	30.3	16	17	17	94.1
	Aug	147.6	16	16	23	82.6
	Sep	182.7	15	15	20	80.0
1990	May	1.8	22	22	22	100.0
	Jun	72.7	15	17	20	90.0
	Jul	71.2	13	12	18	94.4
1991	Aug	58.9	22	22	22	90.9
	Sep	99.1	19	18	20	95.0
	May	47.5	20	20	19	100.0
	Jun	39.5	19	20	21	95.2
	Jul	110.2	14	13	17	94.1
	Aug	74.8	18	19	19	94.7
	Sep	62.4	14	15	20	95.0

(Table continued next page)

Table 33. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
(mm/mon.)						
Total		998.7	223	226	258	92.6
Regression output between predicted and observed working days:						
Constant			0.30			
Std Err of Y Estimate			0.968			
R Squared			0.915			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			0.99			
Std Error of coefficient			0.092			

Table 34. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley vegetable field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	45.5	20	19	20	1	95.0
	Nov	12.0	20	20	20	0	100.0
	Dec	8.1	20	20	20	0	100.0
	Jan	15.9	20	20	20	0	100.0
	Feb	6.3	19	19	19	0	100.0
1990	Mar	6.5	21	21	21	0	100.0
	Apr	39.0	16	17	17	1	94.1
	Oct	449.0	5	2	22	3	86.4
	Nov	28.3	14	14	17	2	88.2
	Dec	16.8	18	18	18	0	100.0
1991	Jan	8.0	18	18	18	0	100.0
	Feb	34.8	19	19	19	0	100.0
	Mar	63.4	15	16	17	1	94.1
	Apr	9.5	14	14	14	0	100.0
	Oct	35.5	18	19	19	1	94.7
1992	Nov	91.0	14	14	17	0	100.0
	Dec	6.2	20	20	20	0	100.0
	Jan	180.3	13	16	16	3	81.3
	Feb	16.0	19	19	19	0	100.0

(Table continued next page)

Table 34. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct
		(mm/mon.)				(%)
Total		1073.0	323	325	353	96.6
Regression output between predicted and observed working days:						
Constant			-1.10			
Std Err of Y Estimate			1.096			
R Squared			0.938			
No. of Observations			19			
Degrees of Freedom			17			
X Coefficient			1.07			
Std Error of coefficient			0.07			

Table 35. Results in the prediction of working days and output agreement for tillage operations on Santa Isabel Valley tomato field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct
1989	Jul	160.0	13	12	20	95.0
1990	Aug	33.1	15	17	18	88.9
	Sep	79.9	17	18	19	84.2
1991	Aug	81.2	17	17	20	80.0
	Sep	67.3	12	12	19	89.5
Total			74	76	96	87.5
Regression output between predicted and observed working days:						
Constant			-2.73			
Std Err of Y Estimate			1.193			
R Squared			0.877			
No. of Observations			5			
Degrees of Freedom			3			
X Coefficient			1.21			
Std Error of coefficient			0.26			

Table 36. Results in the prediction of working days and output agreement for non-tillage operations on Santa Isabel Valley tomato field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	15.3	11	13	13	2	84.6
	Nov	0.0	16	16	16	0	100.0
	Dec	16.0	19	19	19	0	100.0
	Jan	12.2	19	21	21	2	90.5
1990	Feb	3.8	19	19	19	0	100.0
	Mar	1.3	19	19	19	0	100.0
	Apr	26.2	9	9	9	0	100.0
	Oct	393.2	2	4	22	2	90.9
1991	Nov	16.5	12	15	16	3	81.3
	Dec	33.0	18	18	18	0	100.0
	Jan	6.0	20	20	20	0	100.0
	Feb	25.4	19	19	19	0	100.0
1992	Mar	72.2	18	17	18	1	94.4
	Apr	0.0	21	21	21	0	100.0
	Oct	24.2	18	19	19	1	94.7
	Nov	97.8	13	12	16	3	81.3
1992	Dec	6.3	21	21	21	0	100.0
	Jan	134.6	19	20	20	1	95.0
	Feb	15.2	19	19	19	0	100.0

(Table continued next page)

Table 36. (cont'd).

Year	Month	Prec.	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
(mm/mon.)						
Total		889.2	312	321	345	95.7
Regression output between predicted and observed working days:						
Constant			2.06			
Std Err of Y Estimate			0.991			
R Squared			0.955			
No. of Observations			19			
Degrees of Freedom			17			
X Coefficient			0.90			
Std Error of coefficient			0.048			

Table 37. Results in the prediction of working days and output agreement for tillage operations on Guanica Valley vegetable fields location using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Jul	11.2	11	11	11	0	100.0
	Aug	59.9	17	19	20	4	80.0
	Sep	261.7	7	9	19	2	89.5
	May	14.4	18	20	20	2	90.0
	Jun	134.0	14	15	17	3	82.4
1990	Jul	125.4	11	14	17	3	82.4
	Aug	62.5	23	22	23	1	95.7
	Sep	192.3	15	15	19	4	78.9
	May	59.6	20	20	20	0	100.0
	Jun	7.1	19	19	19	0	100.0
1991	Jul	55.2	17	19	20	4	80.0
	Aug	82.6	19	21	22	2	90.9
	Sep	64.2	16	18	19	2	89.5

(Table continued next page)

Table 37. (cont'd).

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
Total		1130.7	207	222	246	89.0
Regression output between predicted and observed working days:						
Constant			3.05			
Std Err of Y Estimate			1.147			
R Squared			0.923			
No. of Observations			13			
Degrees of Freedom			11			
X Coefficient			0.88			
Std Error of coefficient			0.08			

Table 38. Results in the prediction of working days and output agreement for non-tillage operations on Guanica Valley vegetable field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1989	Oct	34.5	10	13	14	3	78.6
	Nov	137.6	10	9	17	3	82.4
	Dec	0.0	12	12	12	0	100.0
	Jan	3.3	18	18	18	0	100.0
1990	Feb	2.5	18	18	18	0	100.0
	Mar	32.3	16	18	18	2	88.9
	Apr	70.3	14	15	16	3	81.3
	Oct	430.9	11	8	22	5	77.3
1991	Nov	65.5	15	14	16	2	87.5
	Dec	10.9	15	15	15	0	100.0
	Jan	0.0	17	17	17	0	100.0
	Feb	35.6	16	17	17	1	94.1
	Mar	102.3	18	17	18	1	94.4
	Apr	47.2	21	21	21	0	100.0
	Oct	53.1	14	14	14	0	100.0
	Nov	99.0	11	11	13	2	84.6
	Dec	13.2	13	14	14	1	92.9

(Table continued next page)

Table 38. (cont'd).

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days	
			Observed	Predicted	Total	Percent Correct (%)
Total		1138.2	249	251	280	91.8
Regression output between predicted and observed working days:						
Constant			0.14			
Std Err of Y Estimate			1.36			
R Squared			0.855			
No. of Observations			17			
Degrees of Freedom			15			
X Coefficient			1.00			
Std Error of coefficient			0.106			

Table 39. Results in the prediction of working days and output agreement for tillage operations performed by crawler tractors on Guanica Valley vegetable field locations using modified Babeir et al. (1986) model.

Year	Month	Prec. (mm/mon.)	Working Days		Observed Days		
			Observed	Predicted	Total	Output Disagreement	Percent Correct (%)
1990	May	14.4	21	22	22	1	95.5
	Jun	134.0	19	18	20	2	90.0
	Jul	125.0	16	16	19	2	89.5
	Aug	62.5	22	22	23	0	100.0
	Sep	193.0	16	15	19	1	94.7
1991	May	59.6	21	22	22	1	95.5
	Jun	7.1	20	20	20	0	100.0
	Jul	55.2	20	20	21	2	90.5
	Aug	82.6	21	21	22	0	100.0
	Sep	64.2	18	19	20	1	95.0
Total			194	195	208	10	95.2
Regression output between predicted and observed working days:							
Constant			-2.59				
Std Err of Y Estimate			0.718				
R Squared			0.927				
No. of Observations			10				
Degrees of Freedom			8				
X Coefficient			1.14				
Std Error of coefficient			0.11				

particularly in the first layer after insignificant rainfalls (less than 5 mm).

Tillage operations for the Santa Isabel Valley tomato fields location was the most difficult to predict. Tillage operation criteria for each layer ($T_i = 92$) were the best for the prediction of working days in this test. A reason could be the low monthly observed data for tillage operations (5 months).

It is important to indicate that DRN and DFF could vary for the same location but for different field operations. It seems that the use of crop coefficients (K_c) and low DFF values for tillage operations predict SMC depletion a little on the slow side, hence avoiding underestimation of working days.

B. Sensitivity Analysis.

1. Modified Hunt (1986) model sensitivity analysis.

Results for the SMC criterion test are presented in Table 40. The modified Hunt (1986) model, like the others is affected firstly by daily rainfall. The results of this test indicate that by increasing tillage operations criterion (T) from 80% to 85%, the number of working days increased from 155 to 170 (9%). When T was changed from 80% to 90% the computed working days increased 21%. The difference in the computation of working days is not marked

Table 40. Sensitivity analysis results for modified Hunt (1986) model testing working day operation criteria in the computation of working days for the Santa Isabel Valley tomato fields location.

Year	Month	Prec. (mm/mon.)	Computed Field Working Days Using Different Operation Criteria					
			A ⁺	B	C	D	E	F
1989	Jul	25	26 ⁺	28	30	--	--	--
	Aug	187	9	14	17	--	--	--
	Sep	160	6	7	13	--	--	--
	Oct	15	--	--	--	30 [#]	31	31
	Nov	0	--	--	--	30	30	30
1990	Dec	16	--	--	--	31	31	31
	Jan	12	--	--	--	31	31	31
	Feb	3	--	--	--	28	28	28
	Mar	0	--	--	--	31	31	31
	Apr	26	--	--	--	30	30	30
	May	0	31	31	31	--	--	--
	Jun	62	16	17	19	--	--	--
	Jul	56	18	20	24	--	--	--
	Aug	33	30	31	31	--	--	--
	Sep	80	19	22	24	--	--	--
	Oct	393	--	--	--	0	2	5
	Nov	16	--	--	--	24	28	28
	Dec	33	--	--	--	30	31	31

(Table continued the next page)

Table 40. (cont'd).

Year	Month	Prec. (mm/mon.)	Computed Field Working Days per Month Using Different Operation Criteria					
			A*	B	C	D	E	F
1991	Jan	6	--	--	--	31	31	31
	Feb	25	--	--	--	28	28	28
	Mar	72	--	--	--	29	30	30
	Apr	0	--	--	--	30	30	30
Total		1220	155	170	189	383	392	395

Legend:

+ - Description of model runs:

Tillage field operation criteria (T)

A = 80%

B = 85%

C = 90%

Non-tillage field operation criteria (TN)

D = 90%

E = 95%

F = 99%

* - Assumed tillage operation period May to September.
 # - Assumed non-tillage operation period October to April.

Table 41. Sensitivity analysis results for modified Hunt (1986) model testing soil parameters.

Month	Prec.	Runoff	SMC mean 150 mm depth	Number of Days with SMC at or above FC
	(mm/mon.)		(mm/day)	(days/mon.)
RNC = 0.5				
Jun	72.7	37.2	33.0	0
Jul	71.3	28.3	33.0	0
Aug	58.6	21.4	32.0	0
				0
RNC = 1.0				
Jun	72.7	27.3	34.6	5
Jul	71.3	18.6	34.8	6
Aug	58.6	15.3	34.7	3
				14
RNC = 1.5				
Jun	72.7	22.6	35.5	5
Jul	71.3	12.4	35.4	6
Aug	58.6	11.7	35.6	3
				14

changing non-tillage operations criterion (TN) because the amount of rainfall was low compared with the rainfall during the tillage operation periods. It can be concluded from this test that this model is not really sensitive to low rainfalls. The model output is affected when the changes on T and TN increased 5%.

In the soil parameters test, the model was analyzed for responses in the runoff coefficient (RNC) variations. Table 41 presents these results. Using this model, the SMC decreased to the WP rapidly. RNC of 0.5 increased the runoff from the soil; the SMC was low compared with results obtained from RNC of 1 or 1.5. FC was not reached on any day.

When RNC was 1 or greater, the number of days at or above FC were the same even the mean SMC for all the months was higher for RNC 1.5. RNC affected the most when is equal to or more than 1.

2. Modified Tulu et al. (1974) model sensitivity analysis.

Tillage operation criteria (T_i) and non-tillage operation criteria (TN_i) for each layer were varied in the sensitivity analysis for SMC criteria test. Results are presented in Table 42. The model is very sensitive to the changes in the operation criteria especially in the third layer. The model was also affected when the changes in T_i

Table 42. Sensitivity analysis results for modified Tulu et al. (1974) model testing working day operation criteria in the computation of working days for Santa Isabel Valley tomato fields location.

Year	Month	Prec. (mm/mon.)	Computed Field Working Days per Month Using Different Operation Criteria							
			A*	B	C	D	E	F	G	H
1989	Jul	25	28*	28	28	--	--	--	--	--
	Aug	187	4	15	15	--	--	--	--	--
	Sep	160	0	16	16	--	--	--	--	--
	Oct	15	--	--	--	28 [#]	28	28	28	28
	Nov	0	--	--	--	30	30	30	30	30
1990	Dec	16	--	--	--	29	29	29	29	29
	Jan	12	--	--	--	30	30	30	30	30
	Feb	3	--	--	--	28	28	28	28	28
	Mar	0	--	--	--	31	31	31	31	31
	Apr	26	--	--	--	28	28	28	28	28
	May	0	31	31	31	--	--	--	--	--
	Jun	6	13	21	21	--	--	--	--	--
	Jul	56	14	22	22	--	--	--	--	--
	Aug	33	21	27	27	--	--	--	--	--
	Sep	80	2	20	20	--	--	--	--	--
	Oct	393	--	--	--	1	2	2	2	2
	Nov	16	--	--	--	22	24	26	26	26
	Dec	33	--	--	--	29	29	29	29	29

(Table continued next page)

Table 42. (cont'd).

Year	Month	Prec. (mm/mon.)	Computed Field Working Days per Month Using Different Operation Criteria							
			A ⁺	B	C	D	E	F	G	H
1991	Jan	6	--	--	--	31	31	31	31	31
	Feb	25	--	--	--	24	24	24	25	25
	Mar	72	--	--	--	25	25	26	26	27
	Apr	0	--	--	--	30	30	30	30	30
Total			113	180	180	366	369	372	373	374

Legend:

+ - Description of model runs:

Tillage field operation criteria

A = T₁ at 90%, T₂ at 95%, and T₃ at 95%.B = T₁ at 90%, T₂ at 95%, and T₃ at 99%C = T₁ at 95%, T₂ at 95%, and T₃ at 99%

Non-tillage field operation criteria

D = TN₁ at 96%, TN₂ at 98%, and TN₃ at 98%.E = TN₁ at 96%, TN₂ at 98%, and TN₃ at 98.5%F = TN₁ at 96%, TN₂ at 98%, and TN₃ at 99%G = TN₁ at 98%, TN₂ at 98%, and TN₃ at 99%H = TN₁ at 99%, TN₂ at 99%, and TN₃ at 99%

* - Assumed tillage operation period May to September.

- Assumed non-tillage operation period October to April.

Table 43. Sensitivity analysis results for modified Tulu et al. (1974) model testing soil parameters.

Month	Prec.	Runoff	SMC Mean 150 mm depth	Number of Days with SMC at or above FC			
				Layer Num.		150 mm depth	
				1	2	3	
	— (mm/mon.) —		(mm/day)	— (days/mon.) —			
RNC = 0.5*							
Jun	72.7	38.4	33.9	5	3	0	0
Jul	71.3	33.6	37.5	8	5	0	3
Aug	58.6	24.2	36.8	<u>3</u>	<u>1</u>	<u>1</u>	<u>1</u>
				16	9	1	4
RNC = 1.0*							
Jun	72.7	26.3	34.4	5	4	2	3
Jul	71.3	21.4	37.7	8	5	5	5
Aug	58.6	17.7	36.8	<u>4</u>	<u>2</u>	<u>2</u>	<u>2</u>
				17	11	9	10
RNC = 1.5*							
Jun	72.7	19.4	34.7	5	4	3	3
Jul	71.3	15.2	37.8	8	5	5	5
Aug	58.6	11.1	37.8	<u>4</u>	<u>2</u>	<u>2</u>	<u>2</u>
				17	11	9	10
DRN = 0.5 [#]							
Jun	72.7	37.4	36.4	10	7	5	8
Jul	71.3	26.7	39.9	11	8	10	8
Aug	58.6	18.2	39.9	<u>11</u>	<u>6</u>	<u>8</u>	<u>6</u>
				32	21	23	22

(Table continued next page)

Table 43. (cont'd).

Month	Prec.	Runoff	SMC Mean 150 mm depth	Number of Days with SMC at or above FC			
				Layer Num.			150 mm depth
				1	2	3	
	— (mm/mon.) —		(mm/day)	— (days/mon.) —			
DRN = 0.75 [#]							
Jun	72.7	29.6	35.4	7	6	4	5
Jul	71.3	24.8	38.9	9	6	9	6
Aug	58.6	18.3	38.7	<u>7</u>	<u>3</u>	<u>4</u>	<u>3</u>
				23	15	16	14
DRN = 1.0 [#]							
Jun	72.7	26.3	34.4	5	4	2	3
Jul	71.3	21.4	37.7	8	5	5	5
Aug	58.6	17.7	36.8	<u>4</u>	<u>2</u>	<u>2</u>	<u>2</u>
				16	11	9	10

Legend:

- * - DRN was assumed as 1
- # - RNC was assumed as 1

and TN_1 occurred from 95% or above. This is because the SMC in any layer is always high. A great impact occurred when T_3 was changed from 95% to 99%. The amount of computed working days increased 59% (from 113 to 180). Changing T_1 from 90 to 95% has no effect on the overall computation of working days. When TN_3 was changed only 0.5% (from 98% to 98.5%) the amount of computed days increased from 366 to 369. Increasing TN_3 from 98% to 99% increased the computed working days in 1.6% (from 366 to 372). This results indicate that changing the operation criteria only 0.5% may affect the PWD computation.

One important aspect when considering a change in the soil parameters sensitivity analysis (test two) is the high number of days with SMC at or above FC in the first layer. Results for the soil parameter test are showed in Table 43.

SMC mean in the top 150 mm of the soil profile remained higher than in modified Hunt (1986) model test for all the months and in all the cases (See Table 43). When more runoff is allowed ($RNC = 0.5$) in Tulu et al. (1974) modified model the number of days with SMC at or above the FC in the first layer remained high but lower in the lower layers. Increasing RNC from 0.5 to 1 increased the number of days at or near FC in lower layers. Changing RNC from 1 to 1.5 does not have a great effect in the SMC mean and in the number of days with SMC above the FC. This is because the layers drained the water at their maximum rate maintaining always a constant SMC in the layers.

Lowering drainage coefficient for each layer (DRN_i) to 0.5 increased the number of days with SMC above FC dramatically in all layers. This is because the amount of water drained from each layer is halved compared with a DRN_i equal to 1. Changing DRN from 0.5 to 1 also raised the mean SMC. It is concluded that Tulu et al. (1974) modified model is really sensitive to changes in RNC and DRN.

3. Modified Babeir et. al (1986) model sensitivity analysis.

The sensitivity analysis consisted of the same changes in T_1 , TN_i , RNC and DRN which were used for studying the modified Tulu et. al (1974) model. This was done to avoid big differences between the two models during the performance of the two tests. Soil parameter tests included also the effect of DFF over the SMC.

SMC criteria test results are presented in Table 44. This model in general is not sensible in the changes in the SMC criteria above 95% compared with modified Tulu et al. (1974) model (See Table 44). The main effect can be observed in the change of T_1 from 90% to 95%. The total number of working days computed increased 10% (from 157 to 173). Additional change in the computed working days for non-tillage operations occurred when TN_1 and TN_2 were increased from 98% to 99% (from 369 to 380). This change occurred although the monthly rainfall was low. It

concluded that the principal effect can be observed when the tillage working day operation criteria is changed in the first two layers 95% or above and the principal effect can be observed when the non-tillage working day operation criteria is changed in the first two layers to 98% or above.

Soil parameters test results for modified Babeir et al. (1986) model are presented in Table 45. The most important effect over the number of days at or above FC was found when all the soil parameters were varied.

RNC shows an effect over the number of days at or above FC. When the RNC was equal to 0.5, no days at or above FC were computed for the 150 mm soil layer. The number of days at or above FC in layer three were higher than for the other layers. This is because the diffusion of water from the fourth layer, that works like a source of water, increased the SMC in the third layer. Secondly the third layer has the least ET contribution in the daily ET (only 5%), then the SMC depletion from the third layer is low. There is a proportional relationship in the number of days at or above FC in the three layers and in the 150 mm soil profile when RNC increases to 1 and 1.5.

DRN is the soil parameter that has the greater impact over the number of days at or above FC. Using a DRN less than 1 (0.5 and 0.75) resulted in a big number of days at or above FC. For this reason is suggested to use DRN coefficient equal to 1.

The change in DFF also increased the number of days at

Table 44. Sensitivity analysis results for modified Babeir et al. (1986) model testing working day operation criteria in the computation of working days for Santa Isabel Valley tomato fields location.

Year	Month	Prec. (mm/mon.)	Computed Field Working Days per Month Using Different Operation Criteria							
			A ⁺	B	C	D	E	F	G	H
1989	Jul	25	26*	26	27	--	--	--	--	--
	Aug	187	12	12	14	--	--	--	--	--
	Sep	160	12	12	16	--	--	--	--	--
	Oct	15	--	--	--	29 [#]	29	30	30	31
	Nov	0	--	--	--	30	30	30	30	30
1990	Dec	16	--	--	--	30	30	30	30	30
	Jan	12	--	--	--	28	28	28	28	30
	Feb	3	--	--	--	28	28	28	28	28
	Mar	0	--	--	--	31	31	31	31	31
	Apr	26	--	--	--	26	26	26	26	28
	May	0	31	31	31	--	--	--	--	--
	Jun	62	17	17	19	--	--	--	--	--
	Jul	56	19	19	21	--	--	--	--	--
	Aug	33	25	25	27	--	--	--	--	--
	Sep	80	15	15	18	--	--	--	--	--
	Oct	393	--	--	--	2	2	2	2	3
	Nov	16	--	--	--	25	25	25	25	25
	Dec	33	--	--	--	28	28	28	28	29

(Table continued next page)

Table 44. (cont'd).

Year	Month	Prec. (mm/mon.)	Computed Field Working Days per Month Using Different Operation Criteria							
			A ⁺	B	C	D	E	F	G	H
1991	Jan	6	--	--	--	29	29	29	29	30
	Feb	25	--	--	--	25	25	25	25	26
	Mar	72	--	--	--	28	28	28	28	29
	Apr	0	--	--	--	30	30	30	30	30
Total			157	157	173	369	369	369	369	380

Legend:

+ - Description of model runs:

Tillage field operation criteria

A = T₁ at 90%, T₂ at 95%, and T₃ at 95%.B = T₁ at 90%, T₂ at 95%, and T₃ at 99%C = T₁ at 95%, T₂ at 95%, and T₃ at 99%

Non-tillage field operation criteria

D = TN₁ at 96%, TN₂ at 98%, and TN₃ at 98%.E = TN₁ at 96%, TN₂ at 98%, and TN₃ at 98.5%F = TN₁ at 96%, TN₂ at 98%, and TN₃ at 99%G = TN₁ at 98%, TN₂ at 98%, and TN₃ at 99%H = TN₁ at 99%, TN₂ at 99%, and TN₃ at 99%

* - Assumed tillage operation period May to September.

- Assumed non-tillage operation period October to April.

Table 45. Sensitivity analysis results for modified Babeir et al. (1986) model testing soil parameters.

Month	Prec.	Runoff	SMC Mean 150 mm depth	Number of Days with SMC at or above FC			
				Layer Num.			150 mm depth
				1	2	3	
	— (mm/mon.) —		(mm/day)	— (days/mon.) —			
RNC = 0.5*							
Jun	72.7	34.5	33.4	0	0	6	0
Jul	71.3	26.2	33.1	1	0	5	0
Aug	58.6	20.6	33.0	<u>0</u>	<u>0</u>	<u>2</u>	<u>0</u>
				1	0	13	0
RNC = 1.0*							
Jun	72.7	22.4	34.3	3	3	4	3
Jul	71.3	13.8	34.2	4	3	6	3
Aug	58.6	12.6	34.5	<u>2</u>	<u>1</u>	<u>4</u>	<u>1</u>
				9	7	14	7
RNC = 1.5*							
Jun	72.7	14.4	33.8	4	3	5	3
Jul	71.3	7.9	34.1	5	4	6	4
Aug	58.6	7.0	33.8	<u>2</u>	<u>1</u>	<u>4</u>	<u>1</u>
				11	8	15	8
DRN = 0.5**							
Jun	72.7	21.1	34.6	5	7	7	2
Jul	71.3	14.3	35.0	2	7	7	4
Aug	58.6	14.3	36.7	<u>2</u>	<u>7</u>	<u>7</u>	<u>4</u>
				9	21	21	10
DRN = 0.75**							
Jun	72.7	22.3	35.1	4	7	7	3
Jul	71.3	14.1	35.1	3	9	8	4
Aug	58.6	14.3	36.1	<u>0</u>	<u>8</u>	<u>7</u>	<u>3</u>
				7	24	22	10

(Table continued next page)

Table 45. (cont'd).

Month	Prec.	Runoff	SMC Mean 150 mm depth	Number of Days with SMC at or above FC			
				Layer Num.		150 mm depth	
				1	2	3	
	— (mm/mon.) —		(mm/day)	— (days/mon.) —			
DRN = 1.0**							
Jun	72.7	22.4	34.3	3	3	4	3
Jul	71.3	13.8	34.2	4	3	6	3
Aug	58.6	12.6	34.5	<u>2</u>	<u>1</u>	<u>4</u>	<u>1</u>
				9	7	14	7
DFF = 0.5#							
Jun	72.7	24.7	33.8	3	3	2	2
Jul	71.3	16.2	34.1	5	3	2	2
Aug	58.6	14.0	34.7	<u>2</u>	<u>2</u>	<u>0</u>	<u>1</u>
				10	8	4	5
DFF = 0.75#							
Jun	72.7	23.9	33.9	3	3	2	2
Jul	71.3	15.0	34.1	6	3	3	3
Aug	58.6	13.3	34.5	<u>2</u>	<u>2</u>	<u>1</u>	<u>1</u>
				11	8	6	6
DFF = 1.0#							
Jun	72.7	22.4	34.3	3	3	4	3
Jul	71.3	13.8	34.2	4	3	6	3
Aug	58.6	12.6	34.5	<u>2</u>	<u>1</u>	<u>4</u>	<u>1</u>
				9	7	14	7

Legend:

- * - DRN and DFF were assumed as 1
- ** - RNC and DFF were assumed as 1
- # - RNC and DRN were assumed as 1

or above FC. When DFF was assigned to 0.5 the number of days at or above FC in layer one was higher than in the second and the third layers. The reason is because less water is diffused from the first to the lower layers. Changing DFF to 1 the number of days at or above FC in layers one and two decreased and increased in layer three. This is because the runoff was low and more water entered the soil and infiltrated directly to the fourth layer (remember DRN was 1). Because the SMC in the fourth layer is greater than the SMC in the third layer the latter is receiving additional water from the fourth layer increasing its SMC.

C. Soil moisture measurements.

Figures 43, 44 , and 45 represent the measured moisture content (dry basis) during the period of August 5 to August 8 1992 for the San Anton silty clay seeded with pumpkins, Santa Isabel clay covered with plastic mulch, and Santa Isabel clay without plastic mulch, respectively (See also Tables E.1, E.2, and E.3).

No statistical analysis was performed to find differences in the SMC between layers and days because the amount of samples (three) collected per day on each field were not sufficient. For that reason all the conclusions addressed from this information are only supposed.

Seven millimeters of rainfall fell early in the morning

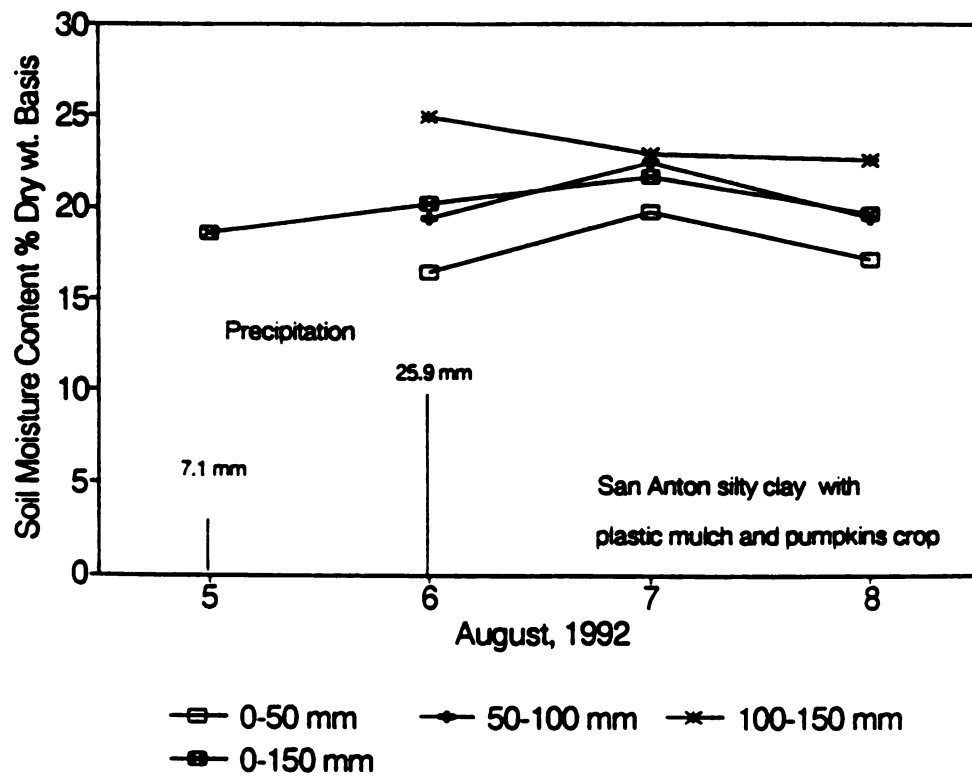


Figure 43. Soil moisture content (SMC) measurements for the San Anton silty clay soil with plastic mulch and pumpkins crop treatment.

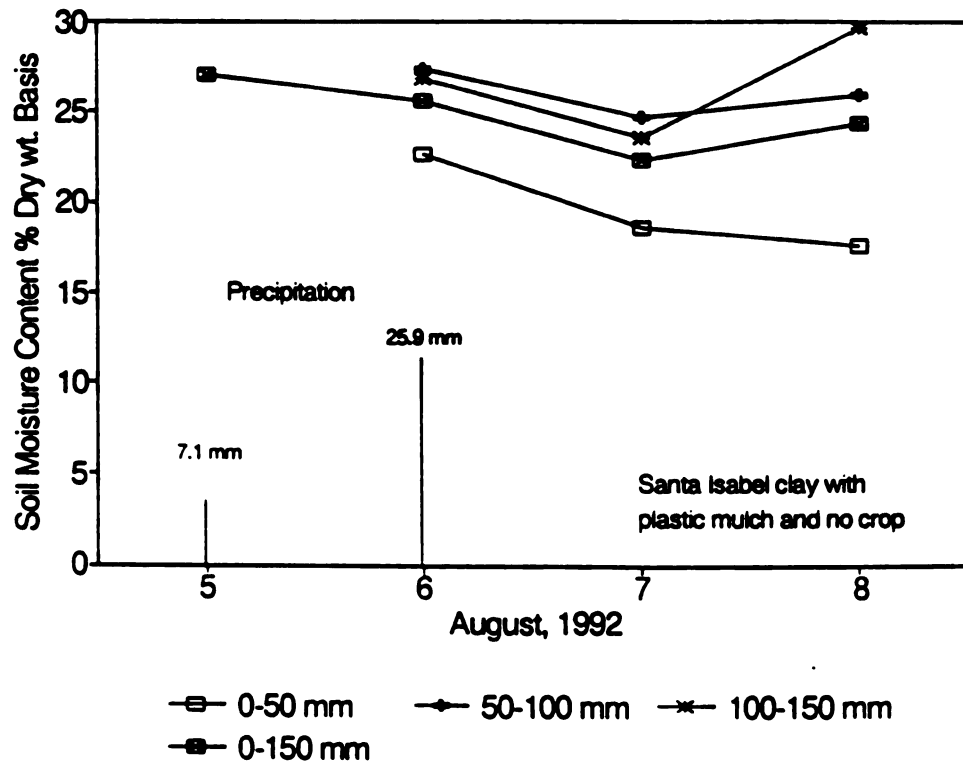


Figure 44. Soil moisture content (SMC) measurements for the Santa Isabel clay soil with plastic mulch and no crop treatment.

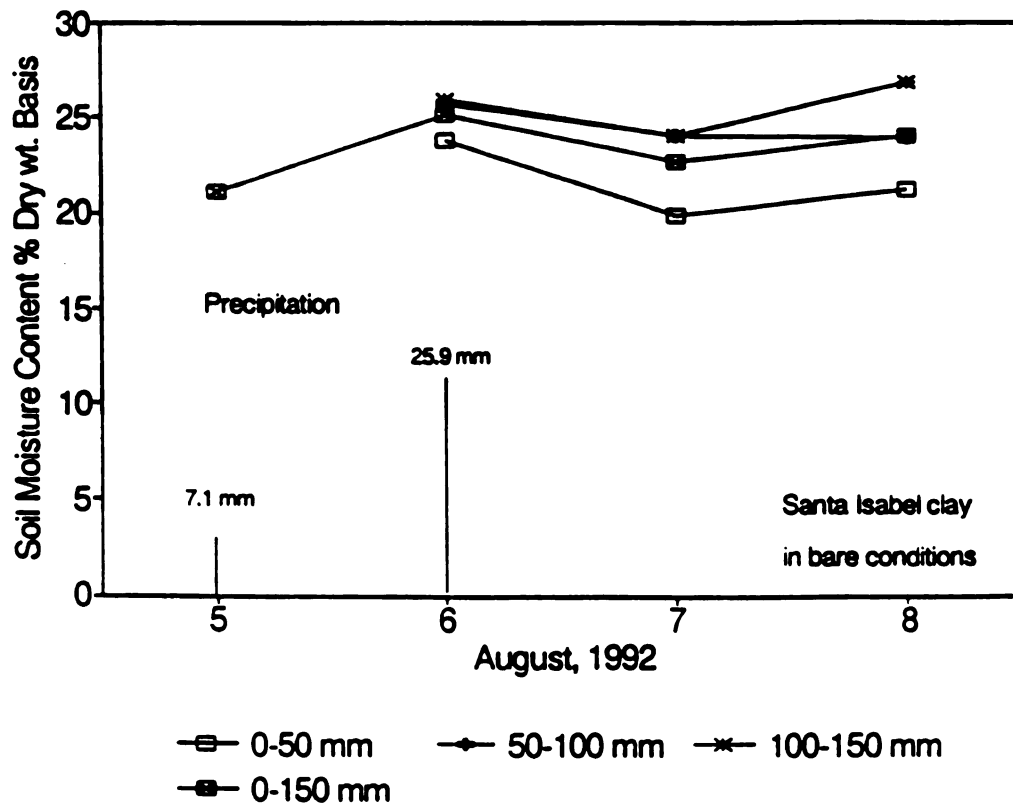


Figure 45. Soil moisture content (SMC) measurements for the Santa Isabel clay soil in bare conditions treatment.

(3:00 am) of August 5. Rainfall of 26 mm fell on August 5 at 7:00 pm and was reported in the morning of August 6.

In all treatments the SMC in the 0-50 mm layer was less than in the lower layers. This happened because the soil samples were taken 12 hours or more after the rainfall. The water may have been depleted rapidly from the soil by evaporation from the upper layer. Another reason is that the soil cracks permitted the infiltration of water to the second and the third layer.

In the first treatment the depletion of water occurred rapidly from the first two layers. This is possible because the transpiration demand by the pumpkin crop was high. Water in the third layer remained high during August 5 but was reduced during August 7. The reverse occurred with layers one and two. Redistribution and diffusion from the third layer to the second and first layers may have occurred.

The treatments on Santa Isabel clay showed similar moisture behavior except for August 5. The SMC on August 5 in the first 150 mm of soil profile was higher in the treatment covered with plastic mulch than in the uncovered treatment. This is possibly because more water was received in the tractor track due to runoff from the plastic mulch. After the 26 mm rainfall on August 6 the SMC increased in the 150 mm layer in the uncovered treatment but decreased slightly in the plastic mulch treatment. The soil cracks in the plastic mulch treatment may have been closed due to high

SMC during August 5 or during the second rainfall, decreasing the infiltration of water.

The results for treatments 2 and 3 also show that the diffusion of water from deeper layers is possible. During August 8 the SMC in the second and third layers increased. Water may have diffused from deeper layers to the upper layer. It was also concluded that the diffusion of water in the clay soil occurred slower than in silty clay due to the low demand of water from transpiration and the pores size in clay soils. The presence of cracks in the clay soil may permit the infiltration of water to deeper layers (more than 150 mm depth). This water may diffuse to the upper layers two or three days later.

D. Comparison of measured and predicted soil moisture content by the models.

After the analysis of the soil moisture measurements the three models (Hunt, 1986; Tulu et al., 1974, and Babeir et al., 1986) modified for this thesis were run with the weather data for the same period of time. The models' parameters were changed in each model in order to simulate the conditions of the soil moisture measurement treatments. Coefficients that best described the soils for the studied locations were used. Initial moisture content and runoff coefficient (RNC) were assumed as 25 mm/150 mm and 0.5, respectively on each model. Layers' drainage coefficient

(DRN_i) was assumed as 1 for the modified Tulu et al. (1974) and Babeir et al. (1986) models. Diffusion coefficient (DFF) 0.7 was used on modified Babeir et al. (1986) model. K_c of 0.36 was used for Santa Isabel clay treatments. In order to simulate the growth stage of pumpkins crop, 0.9 was used as K_c on San Anton silty clay treatment.

Because the dimensions of the soil moisture measurements were presented in dry weight percent basis and the models SMC outputs were calculated in volume basis (mm/mm soil) only the SMC variations and behavior for the first 150 mm of the soil profile for each day were compared. These comparisons are shown graphically (See Figures 46 to 48).

The SMC trend of the treatments was not the expected according to the rainfall which occurred during the period of this study. The only treatment that responded to the rainfall was the Santa Isabel clay in bare conditions except for August 8. All the modified models predicted this behavior with accuracy. If the possibility of having diffusion from deeper layers were true (See section C) then the trend on the Santa Isabel clay treatments could be accepted. Although the modified Babeir et al. (1986) model had the option to compute diffusion, this model could not predict diffusion of water from deeper layers.

In order to make better comparisons between actual and predicted SMC's having more and better field data especially during the rainy season is suggested.

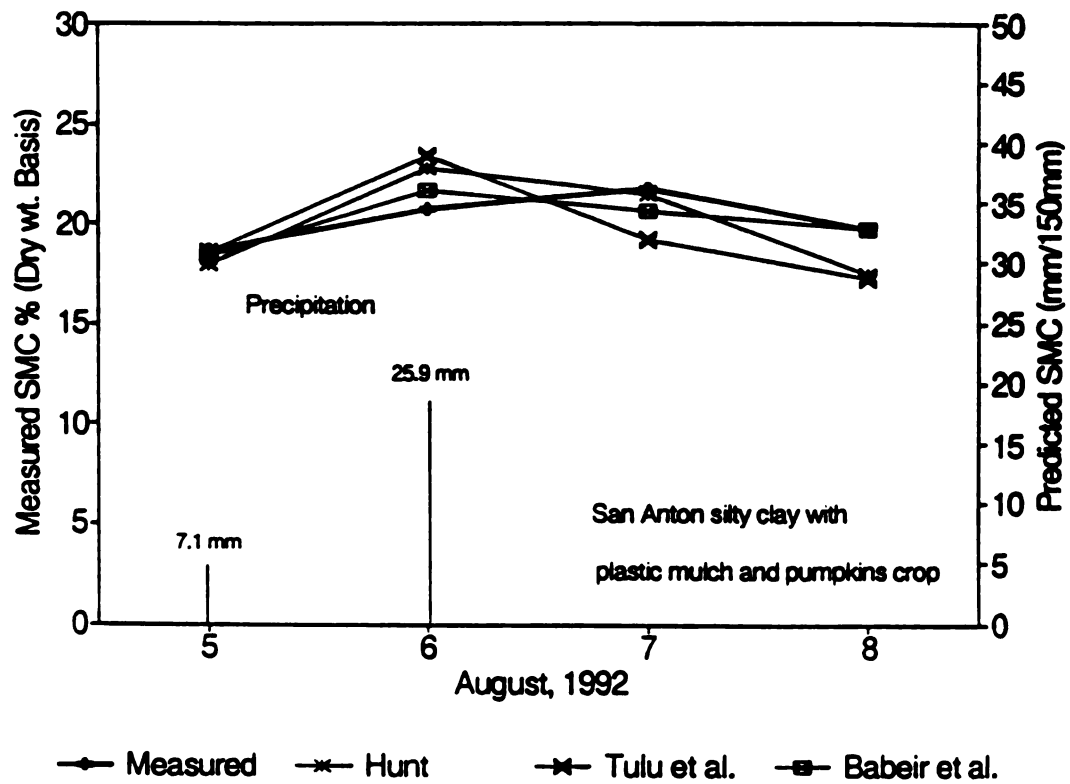


Figure 46. Comparison of measured soil moisture content (SMC) on the San Anton silty clay soil with plastic mulch and pumpkins crop treatment with the modified model outputs.

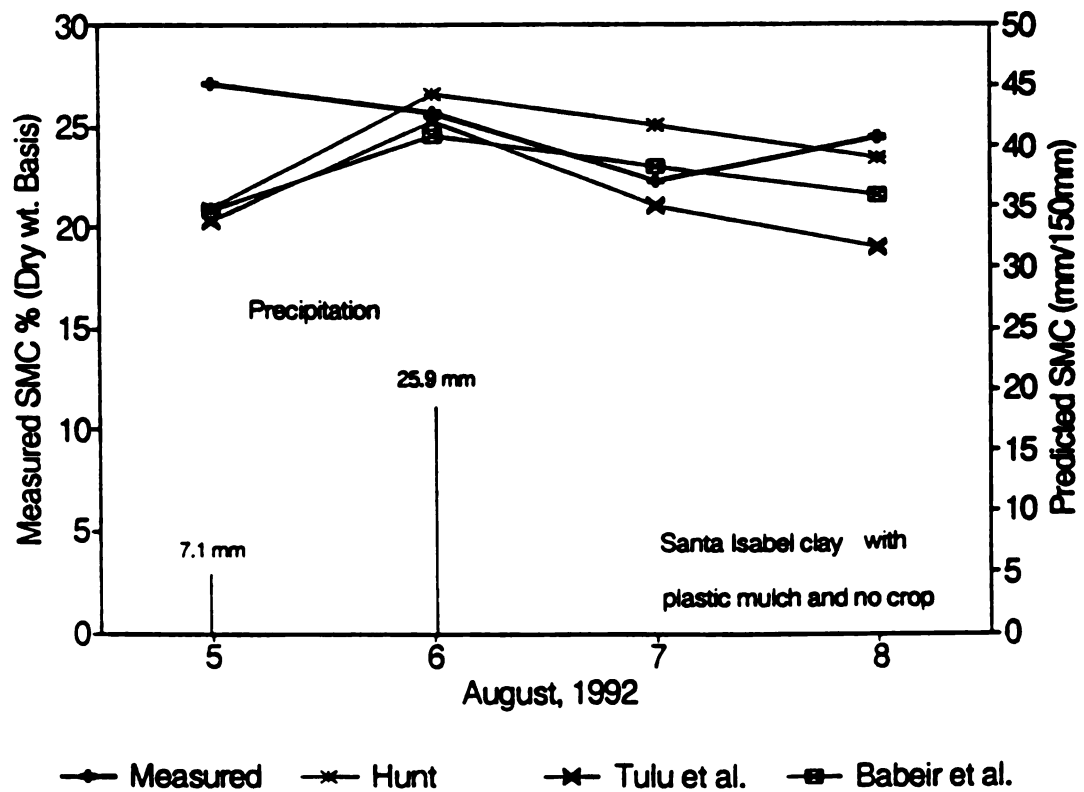


Figure 47. Comparison of measured soil moisture content (SMC) on the Santa Isabel clay soil with plastic mulch and no crop treatment with the modified model outputs.

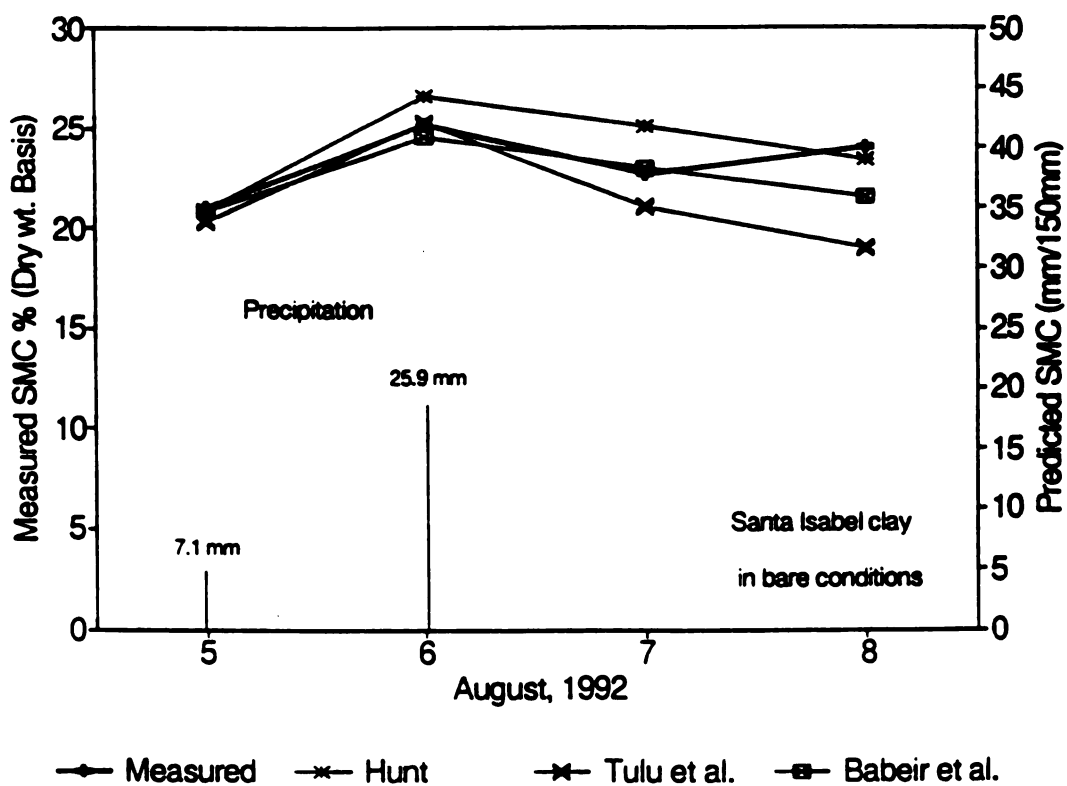


Figure 48. Comparison of measured soil moisture content (SMC) on the Santa Isabel clay soil in bare conditions treatment with the modified model outputs.

E. Selection of a PWD model and PWD tables results.

A model was selected according to its sensitivity on the weather input data, parameters required to simulate the soil moisture, and the validation in the prediction of working days results. The modified Hunt (1986) model was selected to compute the PWD table for all locations. This model is not sensitive to low rainfalls (less than 10 mm). The farmers and farm machinery managers of the south coast interviewed during the summer 1992 agreed that only daily rainfall greater than 20 mm would stop field machinery operations. The model also requires only soil field capacity, permanent wilting point, and runoff coefficient as parameters.

PWD tables were created using the soil parameters and Kc's presented in Tables 11 and 12 respectively, for the referred locations. Field operations criteria and runoff coefficients for each location were the same as presented in Tables 13 and 14. PWD tables based on 16 years of weather data for each location are presented in Tables 46 to 50. The dashes ("--") in the first three columns represent the months when tillage operations is not normally performed. The same symbols in columns four to six represent the months when non-tillage operations are not normally done.

In general PWD's were higher than the expected because the field operation criteria were high. PWD's for May, August, September, and October are lower compared with the

rest of the months. The reason is that the latter are the drier months. PWD's for non tillage operations during the January to April on all the locations were 1.0. The reason is that the non-tillage operations criteria fluctuated between 97 to 99 according to the validation of the modified Hunt (1984) model (See Table 14). PWD's for Santa Isabel Valley vegetable and tomato locations are almost the same even when the rainfall data was different (See Tables 46 and 47, respectively).

PWD's for tillage operations in the Guanica Valley vegetable and performed by crawler tractors locations were different on all the months except on August even when both PWD tables were computed with the same weather data. (See Tables 48 and 49, respectively). That is because the tillage operation criterion was 96% for crawler tractors location and 93% in the other location.

Table 50 presents hypothesized PWD's for sugarcane harvesting in the Santa Isabel Valley because the modified Hunt (1986) model was not validated for this location.

Table 46. Probability of working days (PWD) for field operations at Santa Isabel Valley vegetable location.

Month	PWD for different field operations					
	Tillage			Non-tillage		
	Probability level			Probability level		
	.50	.75	.94	.50	.75	.94
Jan	--	--	--	1.00	1.00	1.00
Feb	--	--	--	1.00	1.00	1.00
Mar	--	--	--	1.00	1.00	1.00
Apr	--	--	--	1.00	1.00	1.00
May	0.96	0.88	0.81	--	--	--
Jun	1.00	0.99	0.93	--	--	--
Jul	1.00	0.96	0.93	--	--	--
Aug	0.98	0.94	0.91	--	--	--
Sep	0.94	0.86	0.80	--	--	--
Oct	--	--	--	0.97	0.94	0.89
Nov	--	--	--	0.96	0.93	0.89
Dec	--	--	--	1.00	1.00	1.00

Table 47. Probability of working days (PWD) for field operations at Santa Isabel Valley tomato location.

Month	PWD for different field operations					
	Tillage			Non-tillage		
	Probability level			Probability level		
	.50	.75	.94	.50	.75	.94
Jan	--	--	--	1.00	1.00	1.00
Feb	--	--	--	1.00	1.00	1.00
Mar	--	--	--	1.00	1.00	1.00
Apr	--	--	--	1.00	1.00	1.00
May	0.96	0.89	0.82	--	--	--
Jun	0.99	0.95	0.90	--	--	--
Jul	1.00	0.97	0.93	--	--	--
Aug	1.00	0.97	0.93	--	--	--
Sep	0.94	0.87	0.82	--	--	--
Oct	--	--	--	0.98	0.95	0.90
Nov	--	--	--	0.99	0.96	0.92
Dec	--	--	--	1.00	1.00	1.00

Table 48. Probability of working days (PWD) for field operations at Guanica Valley vegetable location.

Month	PWD for different field operations					
	Tillage			Non-tillage		
	Probability level			Probability level		
	.50	.75	.94	.50	.75	.94
Jan	--	--	--	1.00	1.00	1.00
Feb	--	--	--	1.00	1.00	1.00
Mar	--	--	--	1.00	1.00	1.00
Apr	--	--	--	1.00	1.00	1.00
May	0.95	0.86	0.80	--	--	--
Jun	1.00	1.00	0.97	--	--	--
Jul	1.00	1.00	1.00	--	--	--
Aug	1.00	0.97	0.92	--	--	--
Sep	0.97	0.87	0.79	--	--	--
Oct	--	--	--	1.00	0.97	0.90
Nov	--	--	--	0.99	0.97	0.95
Dec	--	--	--	1.00	1.00	1.00

Table 49. Probability of working days (PWD) for tillage operations performed with crawler tractors at Guanica Valley vegetable location.

<u>Month</u>	<u>PWD for tillage operations</u>		
	<u>Probability level</u>		
	<u>.50</u>	<u>.75</u>	<u>.94</u>
Jan	--	--	--
Feb	--	--	--
Mar	--	--	--
Apr	--	--	--
May	0.97	0.90	0.83
Jun	1.00	1.00	0.97
Jul	1.00	1.00	1.00
Aug	1.00	0.98	0.94
Sep	0.98	0.90	0.80
Oct	--	--	--
Nov	--	--	--
Dec	--	--	--

Table 50. Hypothesized probability of working days (PWD) for sugarcane harvesting operations performed with combine machines at Santa Isabel Valley location.

<u>Month</u>	<u>PWD for sugarcane harvesting operations</u>		
	<u>Probability level</u>		
	<u>.50</u>	<u>.75</u>	<u>.94</u>
Jan	--	--	--
Feb	--	--	--
Mar	--	--	--
Apr	1.00	1.00	0.98
May	0.98	0.92	0.87
Jun	--	--	--
Jul	--	--	--
Aug	--	--	--
Sep	--	--	--
Oct	--	--	--
Nov	--	--	--
Dec	--	--	--

MICHIGAN STATE UNIV. LIBRARIES



31293008927299

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 00892 7398

LIBRARY
Michigan State
University

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

MSU Is An Affirmative Action/Equal Opportunity Institution

c:\circ\dstduea.pm3-p.

SELECTION OF A MODEL FOR PREDICTING WORKING DAYS
FOR FIELD OPERATIONS IN THE SOUTH COAST OF PUERTO RICO

By

Carlos I. Semidei

Volume II

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Agricultural Technology and System Management
Department of Agricultural Engineering

1993

V. CONCLUSIONS

Three models to predict field operations working days for the south coast of Puerto Rico have been evaluated. The models used in this study computed PWD based on the soil moisture content for the first 150 mm of the soil profile. modified Tulu et al. (1974) and Babeir et al. (1986) models used multiple layer basis. Modified Hunt (1986) model utilized only one layer of 150 mm thick. The following conclusions were derived from the results of this study.

1. The modified Hunt (1986) model that computed soil moisture content using only one layer of 150 mm thick was the most accurate in the prediction of field operations working days.
2. The three modified models can predict non-tillage operations working days with sufficiently high accuracy.
3. Layering the soil causes the models to be sensitive to low rainfalls (e.g. 5 mm), especially in the prediction of tillage operations.

4. The use of alternate rainfall data from other weather station may cause incorrect results.
5. Accuracy in the prediction of working or non-working days on a day-to-day basis is a better evaluation than the prediction of working days on a monthly basis due to under- or over-prediction of working days by the latter method.

VI. RECOMMENDATIONS

The following are the authors recommendations for further study:

1. Prediction of field operations using soil moisture content in a layer basis would be improved with layers of thickness equal or greater than 150 mm.

2. Use of crop coefficient greater than 0.36 in the computation of evapotranspiration for tillage operations months needs to be evaluated.

3. More and better soil moisture field data are required to estimate the runoff, drainage, and diffusion coefficients for the soils of the south coast of Puerto Rico.

VII. REFERENCES

- Acevedo, W. 1992. Sub-Manager Machinery Program of the Agricultural Services Administration-Guanica. Personal communication.
- Agr. Exp. Sta. U.P.R. 1979. Conjunto tecnologico para la produccion de hortalizas. Agr. Exp. Sta. U.P.R. Publ. 102.
- _____. 1983. Conjunto tecnologico para la produccion de cana de azucar. Agr. Exp. Sta. U.P.R. Publ. 103.
- Alamo, C. 1990. Hortalizas. p. 3 In: M. Antoni, M. Cortes, G. Gonzalez. and S. Velez (ed.). Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.
- _____. 1991. Hortalizas. p. 5 In: C. Alamo (ed.) Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.
- _____. 1992. Hortalizas. p. 3 In: C. Alamo (ed.) Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.
- ASA. 1992. Resumen de uso de horas de operadores. Agricultural Services Administration. Unpublished data.
- ASAE. 1984. Agricultural machinery management data. ASAE Standards D230.4. ASAE. St. Joseph, MI 49085.
- Atterberg, A. 1911. Die Plastizitat der tone. Int. Mitt. Bodenk. 1:10-43
- _____. 1912. Die Konsistenz und die Bindigheit der Boden. Int. Mitt. Bodenk. 2:148-89
- Babeir, A. S., T. S. Colvin, and S. J. Marley. 1986. Predicting Field Tractability with a simulation model. TRANSACTIONS of the ASAE 29(6):1520-1525.

- Baier, W. 1973. Estimation of field workdays in Canada from the versatile soil moisture budget. Canadian Agricultural Engineering. 15:84-87.
- _____ and G. W. Robertson. 1966. A new versatile soil moisture budget. Can. J. Plant Sci. 46:299-315.
- Barnes, A. C. 1974. The Sugar Cane. John Wiley & Sons. New York.
- Blaney, H. F. and W. D. Criddle. 1950. Determining water requirements in irrigated areas from climatological and irrigation data. USDA-SCS. TP-96.
- Boehlje, M. and V. R. Eidman. 1984. Farm management. John Wiley & Sons, Inc. New York.
- Capiel, M. and R. J. Calvesbert. 1976. On the climate of Puerto Rico and its agricultural water balance. J. Agric. Univ. P.R. 60(2):139-53.
- Capo, B. G. 1970. La influencia de la edad y la epoca de cosecha sobre el contenido de azucar y la produccion de cana de azucar. Agr. Exp. Sta. U.P.R. Bull 227.
- Carter, O. 1961. Soil survey of the Lajas Valley area, Puerto Rico. USDA-SCS.
- Chilsholm, T. S. 1976. Development of an adjustable rake-type sugarcane piler. J. Agric. Univ. P.R. 60(1): 78-85.
- Collier's encyclopedia. 1992. Macmillan Educational Co. New York.
- Dept. de Agricultura y Trabajo. 1926. Estadisticas. Revista de Agricultura de Puerto Rico. 16(3):171.
- Department of Agriculture of Puerto Rico. 1972. Clima y cosechas. Departamento de Agricultura de Puerto Rico.
- Diaz, L. E. 1992. Soil Scientist. La Montana Regional College. University of Puerto Rico. Personal communication.
- Doorenbos, J. and W. O. Pruitt. 1977. Crop water requirements. FAO Irrigation and Drainage. Paper 24. Pg. 156
- Dyer, J.A. and W. Baier. 1979. Weather-based estimation of field workdays in fall. Canadian Agricultural Engineering. 21:119-122.

- Elliot, R, W. D. Lembke, and D.R. Hunt. 1977. A simulation model for predicting available days for soil tillage. TRANSACTIONS of the ASAE 26(5):1451-1457.
- Farrall, A. and C. F. Albrecht. 1965. Agricultural engineering a Dictionary and handbook. The Interstate Printers & Publishers, Inc. Illinois.
- Fulton, C.V., G. E. Ayres, and E. O. Heady. 1976. Expected number of days suitable for field work in Iowa. TRANSACTIONS of the ASAE 19(6):1045-1047.
- Gierbolini, R. E. 1979. Soil survey of Ponce area of southern Puerto Rico. USDA-SCS.
- Gomez, F. 1970. El cultivo de la cana de azucar. Universidad Central de Venezuela. Alcance No. 15
- Gonzalez, E. 1993. Soil Scientist La Montana Regional College. University of Puerto Rico. Personal communication.
- _____ and M. R. Goyal. 1988. Seasonal consumptive use of water by bell and Cubanelle peppers in semiarid and humid coastal sites in Puerto Rico. J. Agric. Univ. P.R. 72(4): 606-614.
- Goyal, M. R. 1983. Labor input requirements for experimental production of summer peppers under drip irrigation. J. Agric. Univ. P.R. 67(1):22-7.
- _____. 1987. In situ recovery of drip irrigated cabbage roots. J. Agric. Univ. P.R. 71(4):419-21.
- _____. 1988a. Potential evapotranspiration for the south coast of Puerto Rico with Hargreaves-Samani technique. J. Agric. Univ. P.R. 72(1):57-63.
- _____. 1988b. Estimation of seasonal water consumption by selected vegetable crops in the semiarid and humid regions of Puerto Rico. Monograph #88-90, Agr. Exp. Sta. U.P.R.
- _____ and E. Gonzalez. 1989a. Datos climatologicos de las subestaciones experimentales agricolas de Puerto Rico. Agr. Exp. Sta U.P.R. Publ. 88-70
- _____. 1989b. Estimating monthly water consumptive use by sugarcane at four regional sites in Puerto Rico. J. Agric. Univ. P.R. 73(1):00.

- Hargreaves, G. H. and Z. A. Samani. 1985. Reference crop evapotranspiration from temperature. Appl. Eng. Agric., ASAE. 1(2):96-9.
- Hassan, A. E., and R.S. Broughton. 1975. Soil moisture criteria for tractability. Canadian Agricultural Engineering 17:124-129.
- Hawkins, H. R. 1978. Runoff curve numbers with varying site moisture. J. of Irrig. and Drn. Div. Vol. 104 (IR4:330-40).
- Hetz, E. J., A. Gold, and L. E. Reese. 1983. Computer prediction of suitable workdays for mechanized winter wheat operations in Chile. AMA 14(3):62-66.
- Hillel, D. 1977. Computer simulation of soil-water dynamics. International Development Research Centre Ottawa, Canada.
- _____. 1980. Fundamentals of soil physics. Academic Press, Inc. New York.
- Hunt, D. 1986. Engineering Models for Agricultural Production. The AVI Publishing Co., Inc. Connecticut.
- _____. 1983. Farm power and machinery management. The Iowa State University Press. Ames, Iowa.
- IICA. 1985. Compendio de agronomia tropical. Instituto Interamericano de Cooperacion para la Agricultura. San Jose, Costa Rica.
- Jensen, M. E. 1966. Empirical methods for estimating or predicting evapotranspiration using radiation. In: Evapotranspiration and its role in water resources management. ASAE, St. Joseph, MI, 49085
- _____. 1980. Design and operation of farm irrigation systems. Monograph 3 Chapter 6. ASAE, St. Joseph, MI, 49085
- Kachinski, N.A. et al. 1950. Agrophysical Characteristics of the Central Ural Region.
- Kanwar, R. S., H.P. Johnson, and J.L. Baker. 1983. Comparison of simulated and measured nitrate losses in tile effluent. TRANSACTIONS of the ASAE 26(5):1451-1457.
- Knave, D. E and H. C. Mohr. 1967. Distribution of roots of four different vegetables under paper and polyethylene mulches. Am. Soc. Hort. Sci. Vol 91:589-97.

- Land Authority. 1990. Autoridad de tierras E.L.A.
Land Authority of Puerto Rico.
- _____. 1988-1992. Informe semanal de produccion de cosechadoras Claas. Land Authority. Unpublished data.
- Link, A. J. 1968. Research needs for farm machinery scheduling. Computers and Farm Machinery Seminar Proceedings. ASAE Publication PROC-468:28-32
- Lee, W. F., M. D. Boehlje, A. G. Nelson, W. G. Murray. 1988. Agricultural finance. Iowa State University Press. Ames, Iowa.
- Leon, E. 1992. Field operations manager. Land Authority Personal communication.
- Lugo, M. A. 1953. Moisture Relationships of Puerto Rican Soils. Technical paper 9. Agr. Exp. Sta. U.P.R.
- _____, J. M. Wolf, and R. Perez Escolar. 1981. Water loss, intake, movement, retention, and availability in major soils of Puerto Rico. Agr. Exp. Sta. U.P.R. Bull. 264
- Lugo, H. M. , J. Badillo, and F. Ortiz. 1987. Yield response of watermelon, tomato, and pigeon pea to land preparation techniques in southern Puerto Rico. J. Agric. Univ. P.R. 71(2):203-8.
- Lugo-Lopez, M. A. and G. Acevedo. 1956. Effects of tractor-traffic compaction on the physical properties of an irrigated soil in the southwestern Puerto Rico. J. Agric. Univ. P.R. 40(4):235-44.
- Merino, H. 1977. Efecto de la humedad en la preparacion del suelo Coto arcilloso para el cultivo de la soya. Unpublished M.S. thesis, Univ. P.R. R.U.M.
- National Oceanic and Atmospheric Administration. 1977-1992. Climatological data for Puerto Rico and Virgin Islands. Department of Commerce, Washington, D.C.
- Ozkan, H. E. and W. M. Edwards. 1986. A farmer-oriented machinery comparison model. TRANSACTIONS of the ASAE. 29(3):672-677.
- _____, B. He, and R. G. Holmes. 1990. Determining machinery timeliness cost in corn planting using DRAINMOD. TRANSACTIONS of the ASAE. 33(3):718-23.

- Pathak, P., K. B. Laryea, and R. Sudi. 1989. Runoff model for small watershed in the semi-arid tropics. *TRANSACTIONS of the ASAE*. 32(5):1619-24.
- Penman, H. L. 1956. Estimating evapotranspiration. *TRANSACTION Am. Geophys. Union*. 37:43-46.
- Phillips, A. L. 1991. Baling sugarcane tops and leaves. *ASAE Paper PRS 91-007*. ASAE, St. Joseph, MI 49085.
- Pico, R. 1974. The geography of Puerto Rico. Aldine Publishing Co. Chicago, Illinois.
- Portas, C. A. and J. J. Dordio. 1980. Tomato root system, a short review with reference on tomatoes for processing. *Acta Hortic*. 100,113-24.
- Richey, C. B., L. L. Harrold, and F. R. Brooks. 1961. *Agricultural engineers' handbook*. McGraw Hill, New York.
- Rivadeneira, J. 1982. Cambios en las propiedades fisicas del suelo Coto en funcion de metodos de preparacion y su correlacion con el desarrollo de la yautia (*Xanthosoma caracu* Kock y Bouche). Unpublished M.S. thesis, Univ. P.R. R.U.M.
- Rivera, L. 1986. Riego por goteo: su importancia en la agricultura puertorriquena. *Revista Colegio de Agronomos*. April-June.
- Rosenberg, S. E., C. A. Rotz, J. R. Black, and H. Muhtar. 1982. Predicting of suitable days for field work. *ASAE Paper 82-1032*. ASAE, St. Joseph, MI 49085.
- Russell, E. J. and E. W. Russell. 1950. Soil conditions and plant growth. Longman, London.
- Rutledge, P. L., and F. V. McHardy. 1968. The influence of weather on field tractability in Alberta. *Canadian Agricultural Engineering* 10:70-73.
- Samuels, G, S. Alers, and P. Landrau, Jr. 1960. The influence of time of harvest and age of sixteen varieties on their sucrose content. *J. Agric. Univ. P.R.* 44(1):1-10.
- Santiago, J. 1992. Field machinery manager. South Coast Vegetable Program. Personal communication.
- Shayya, W. H. and V. F. Bralts. 1991. Guide to microcomputer irrigation scheduler. Michigan State University, Dept. of Agricultural Engineering.

- Schwab, G. O., Frevert R., Edminister T. and Barnes K. 1981. Soil and Water Conservation Engineering. John Wiley & Sons. Inc. New York.
- Selirio, I. S., and D. M. Brown. 1972. Estimation of spring workday from climatological records. Canadian Agricultural Engineering 14:79-81.
- Shaw, R. W. 1965. Estimation of field working days in the spring from meteorological data. Iowa State J. Sci. 39:393-402.
- Shukla, L. N. 1974. Soil compaction due to harvest traffic in sugarcane fields on a Lajas Valley farm of Puerto Rico. J. Agric. Univ. P.R. 58(3):279-92.
- _____. 1975. Trends in the use of tractor power for sugarcane production in Puerto Rico. J. Agric. Univ. P.R. 59(4):274-78.
- Skaggs, R. W. A water management model for shallow water table soils. Report No 134. Water Resources Research Institute, University of North Carolina, Raleigh.
- Smerage, G. H. 1979. System analysis and agricultural engineering. ASAE National Student Journal. pp. 20-21. University of Florida, Gainesville, Florida.
- Soil Conservation Service. 1972. Estimation of direct runoff from storm rainfall. In: National Engineering Handbook, Section 4, Hydrology. USDA-SCS.
- Thorntwaite, C. W. An approach toward a regional classification of climate. Geogr. Rev. 38(1):55-94.
- _____. 1954. Estimating soil tractionability from climatic data. Publications in climatology. 8(3) The Johns Hopkins University. Centerton, New Jersey
- Troche, J. 1987. Censo de variedades de cana de azucar cultivadas en Puerto Rico en 1985. Agr. Exp. Sta. U.P.R. Bull. 283.
- _____. 1990. Cana de azucar. p. 188 In: M. Antoni, M. Cortes, G. Gonzalez. and S. Velez (ed.). Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.
- _____. 1991. Cana de azucar. p. 208 In: C. Alamo (ed.) Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.

-
- . 1992. Cana de azucar. p. 161 In: C. Alamo (ed.) Situacion y perspectivas empresas agricolas de Puerto Rico. Agr. Exp. Sta. U.P.R.
- Tulu, M. Y., J. B. Joltman, R. B. Friedly, and S. D. Parsons. 1974. Timeliness costs and available working days-shelled corn. TRANSACTIONS of the ASAE 17(5):798-800, 804.
- Verigo, S. A. and L. A. Razumova. 1963. Soil moisture and its significance in agriculture. Israel Program for Scientific Translations. Jerusalem.
- Vicente-Chandler, J., R. Costas, and E. Boneta. 1966. High crop yield produced with or without tillage on three typical soils of the humid region of Puerto Rico. J. Agric. Univ. P.R. 50(2):146-50.
- White, R. G. 1978. Determining capacities of farm machines. Cooperative Extension Service. Michigan State University. Bull. E-1216 SF-14.
- Wolak, F. J. 1981. Development of a field machinery selection model. Unpublished Ph.D dissertation. Michigan State University, East Lansing Mi.
- Wright, A. 1971. Systems analysis in agricultural management. John Wiley, Sidney, Australia.

APPENDIX A

APPENDIX A: Input data and output files examples.

1. Weather input data file
2. Hunt (1986) modified model daily summary output
file
3. Tulu et al. (1974) modified model daily summary
output file
4. Babeir et al. (1986) modified model daily
summary output file
5. Models common bymonthly summary output file
6. Models common monthly summary output file

1. Weather data input file

Weather data input file was created as a DOS text file. The first and second columns present the month and the day of the month, respectively. Daily rainfall data (inches) is shown in the third column. The fourth column presents daily class A pan evaporation data (hundredths of inches). The next example is a common input file for all the modified models.

1989

7	1		
7	1	0	30
7	2	0	30
7	3	0	22
7	4	0	26
7	5	0.42	27
7	6	0.28	34
7	7	0	21
7	8	0	29
7	9	0.03	27
7	10	0	24
7	11	0	30
7	12	0.06	30
7	13	0.05	24
7	14	0	24
7	15	0	33
7	16	0	32
7	17	0	33
7	18	0	30
7	19	0	30
7	20	0	30
7	21	0	30
7	22	0	31
7	23	0.28	32
7	24	0	32
7	25	0.07	31
7	26	0	30
7	27	0	28
7	28	0	20
7	29	0	28
7	30	0	10
7	31	0	10
8	1	0	29
8	2	0	33
8	3	0.36	38
8	4	0	28
8	5	0	31
8	6	0.38	29
8	7	0	28
8	8	0.12	24
8	9	0	29
8	10	0	32
8	11	0.55	22
8	12	0.65	23
8	13	0	26
8	14	0	29
8	15	0	30
8	16	0	31
8	17	0.03	21
8	18	0.25	17
8	19	0.4	32
8	20	0.05	28
8	21	0.06	14
8	22	0.48	30
8	23	0	14
8	24	0.76	20
8	25	0.58	23
8	26	0.31	30
8	27	0	31
8	28	0	13
8	29	0.5	18
8	30	0.33	12
8	31	0	27
9	1	0	24
9	2	0	28
9	3	0.05	26
9	4	0	19
9	5	0	32
9	6	0	33
9	7	0	26
9	8	0	32
9	9	0	32
9	10	0	24
9	11	1.24	24
9	12	0	17
9	13	0	20
9	14	0	27
9	15	0.15	18
9	16	0	24
9	17	0	26
9	18	0.3	20
9	19	0.4	39
9	20	0	19
9	21	0.34	24
9	22	1.41	17
9	23	2.07	3
9	24	1.15	3

9	25	0	22
9	26	0	25
9	27	0	23
9	28	0	16
9	29	0.07	25
9	30	0	20
10	1	0	17
10	2	0.7	23
10	3	0	21
10	4	0	20
10	5	0	21
10	6	0	29
10	7	0	18
10	8	0	23
10	9	0.01	23
10	10	0	25
10	11	0	31
10	12	0	19
10	13	0	24
10	14	0	23
10	15	0	23
10	16	0	20
10	17	0.11	26
10	18	0	21
10	19	0.11	27
10	20	0.06	12
10	21	0.64	12
10	22	0.02	9
10	23	0	20
10	24	0	23
10	25	0	23
10	26	0	20
10	27	0	22
10	28	0	26
10	29	0.1	10
10	30	0.04	23
10	31	0	9
11	1	0	22
11	2	0	17
11	3	0	24
11	4	0	21
11	5	0	23
11	6	0.38	17
11	7	0.02	16
11	8	0	16
11	9	0.07	11
11	10	0	20
11	11	0	19
11	12	0	20
11	13	0	21
11	14	0	23
11	15	0	23
11	16	0	19
11	17	0	21
11	18	0	26
11	19	0	26
11	20	0	21
11	21	0	20
11	22	0	19
11	23	0	25
11	24	0	24
11	25	0	21
11	26	0	20
11	27	0	25
11	28	0	23
11	29	0	27
11	30	0	28
12	1	0	23
12	2	0	29
12	3	0	15
12	4	0.1	19
12	5	0	16
12	6	0	15
12	7	0	20
12	8	0	23
12	9	0	21
12	10	0	28
12	11	0	24
12	12	0	16
12	13	0	19
12	14	0	22
12	15	0	19
12	16	0	14
12	17	0	20
12	18	0	26
12	19	0	24

2. Hunt (1986) modified model daily summary output file

Output of daily soil moisture computations and definition of a working-non-working day for Hunt (1986) modified model is presented in the next example. The first three columns present the date. Potential evapotranspiration, actual evapotranspiration, daily rainfall, runoff, drainage, and soil moisture content are presented in the following columns. The last two columns show the working and non-working day definition according to the soil working day criteria for tillage and non-tillage operations. Number one means the day was a working day and two a non-working day. Symbol "-" means that the date during that specific month was defined to perform the other field operation.

PRINT OUTPUT FILEC:\QB45\EXPHUN.DAY BASED ON HUNT MODEL

WEATHER DATA INPUTFILEC:\QB45\A.IN

DATE:06-23-1993 TIME:21:52:09

SELECTIONS FOR THIS RUN ARE:

1. CROP	VEGETABLES
2. PERMANENT WILTING POINT	25.0 mm/150mm
3. FIELD CAPACITY	45.0 mm/150mm
4. INITIAL MOISTURE CONTENT	30.0 mm/150mm
5. CRITERION FOR TILLAGE OPERATIONS	80 %
6. CRITERION FOR NON-TILLAGE OPERATIONS ..	95 %

YEAR MONTH DAY			PET	ET	RAIN	R-OFF	DRAIN	MOIST	OPERATION	
			mm/day						TILLAGE	NON TILLAGE
1989										
7	1		6.1	5.0	0.0	0.0	0.0	25.0	-	1
7	2		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	3		4.5	0.0	0.0	0.0	0.0	25.0	-	1
7	4		5.3	0.0	0.0	0.0	0.0	25.0	-	1
7	5		5.5	0.0	10.7	0.9	0.0	34.8	-	1
7	6		6.9	6.9	7.1	0.2	0.0	34.8	-	1
7	7		4.3	4.3	0.0	0.0	0.0	30.5	-	1
7	8		5.9	5.5	0.0	0.0	0.0	25.0	-	1
7	9		5.5	0.0	0.8	0.0	0.0	25.8	-	1
7	10		4.9	0.8	0.0	0.0	0.0	25.0	-	1
7	11		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	12		6.1	0.0	1.5	0.0	0.0	26.5	-	1
7	13		4.9	1.5	1.3	0.0	0.0	26.3	-	1
7	14		4.9	1.3	0.0	0.0	0.0	25.0	-	1
7	15		6.7	0.0	0.0	0.0	0.0	25.0	-	1
7	16		6.5	0.0	0.0	0.0	0.0	25.0	-	1
7	17		6.7	0.0	0.0	0.0	0.0	25.0	-	1
7	18		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	19		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	20		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	21		6.1	0.0	0.0	0.0	0.0	25.0	-	1
7	22		6.3	0.0	0.0	0.0	0.0	25.0	-	1
7	23		6.5	0.0	7.1	0.1	0.0	32.0	-	1
7	24		6.5	6.5	0.0	0.0	0.0	25.5	-	1
7	25		6.3	0.5	1.8	0.0	0.0	26.8	-	1
7	26		6.1	1.8	0.0	0.0	0.0	25.0	-	1
7	27		5.7	0.0	0.0	0.0	0.0	25.0	-	1
7	28		4.1	0.0	0.0	0.0	0.0	25.0	-	1
7	29		5.7	0.0	0.0	0.0	0.0	25.0	-	1
7	30		2.0	0.0	0.0	0.0	0.0	25.0	-	1
7	31		2.0	0.0	0.0	0.0	0.0	25.0	-	1
8	1		5.9	0.0	0.0	0.0	0.0	25.0	-	1
8	2		6.7	0.0	0.0	0.0	0.0	25.0	-	1
8	3		7.7	0.0	9.1	0.5	0.0	33.7	-	1
8	4		5.7	5.7	0.0	0.0	0.0	28.0	-	1
8	5		6.3	3.0	0.0	0.0	0.0	25.0	-	1
8	6		5.9	0.0	9.7	0.6	0.0	34.1	-	1
8	7		5.7	5.7	0.0	0.0	0.0	28.4	-	1
8	8		4.9	3.4	3.0	0.0	0.0	28.0	-	1
8	9		5.9	3.0	0.0	0.0	0.0	25.0	-	1
8	10		6.5	0.0	0.0	0.0	0.0	25.0	-	1
8	11		4.5	0.0	14.0	2.1	0.0	36.9	-	1
8	12		4.7	4.7	16.5	4.9	0.0	43.8	-	0
8	13		5.3	5.3	0.0	0.0	0.0	38.5	-	1
8	14		5.9	5.9	0.0	0.0	0.0	32.6	-	1
8	15		6.1	6.1	0.0	0.0	0.0	26.5	-	1
8	16		6.3	1.5	0.0	0.0	0.0	25.0	-	1
8	17		4.3	0.0	0.8	0.0	0.0	25.8	-	1
8	18		3.5	0.8	6.3	0.0	0.0	31.3	-	1
8	19		6.5	6.3	10.2	0.7	0.0	34.4	-	1
8	20		5.7	5.7	1.3	0.0	0.0	30.0	-	1
8	21		2.8	2.8	1.5	0.0	0.0	28.7	-	1
8	22		6.1	3.7	12.2	1.4	0.0	35.8	-	1
8	23		2.8	2.8	0.0	0.0	0.0	33.0	-	1
8	24		4.1	4.1	19.3	5.8	0.0	42.4	-	1
8	25		4.7	4.7	14.7	5.5	1.0	46.0	-	0
8	26		6.1	6.1	7.9	1.7	0.5	45.5	-	0
8	27		6.3	6.3	0.0	0.0	0.0	39.2	-	1
8	28		2.6	2.6	0.0	0.0	0.0	36.6	-	1
8	29		3.7	3.7	12.7	2.9	0.0	42.7	-	1
8	30		2.4	2.4	8.4	2.1	0.8	45.8	-	0
8	31		5.5	5.5	0.0	0.0	0.0	40.3	-	1
9	1		4.9	4.9	0.0	0.0	0.0	35.4	-	1
9	2		5.7	5.7	0.0	0.0	0.0	29.7	-	1

9	3	5.3	4.7	1.3	0.0	0.0	26.3	-	1
9	4	3.9	1.3	0.0	0.0	0.0	25.0	-	1
9	5	6.5	0.0	0.0	0.0	0.0	25.0	-	1
9	6	6.7	0.0	0.0	0.0	0.0	25.0	-	1
9	7	5.3	0.0	0.0	0.0	0.0	25.0	-	1
9	8	6.5	0.0	0.0	0.0	0.0	25.0	-	1
9	9	6.5	0.0	0.0	0.0	0.0	25.0	-	1
9	10	4.9	0.0	0.0	0.0	0.0	25.0	-	1
9	11	4.9	0.0	31.5	12.9	0.0	43.6	-	0
9	12	3.5	3.5	0.0	0.0	0.0	40.1	-	1
9	13	4.1	4.1	0.0	0.0	0.0	36.1	-	1
9	14	5.5	5.5	0.0	0.0	0.0	30.6	-	1
9	15	3.7	3.7	3.8	0.0	0.0	30.7	-	1
9	16	4.9	4.9	0.0	0.0	0.0	25.8	-	1
9	17	5.3	0.8	0.0	0.0	0.0	25.0	-	1
9	18	4.1	0.0	7.6	0.2	0.0	32.4	-	1
9	19	7.9	7.4	10.2	0.7	0.0	34.4	-	1
9	20	3.9	3.9	0.0	0.0	0.0	30.6	-	1
9	21	4.9	4.9	8.6	0.4	0.0	33.9	-	1
9	22	3.5	3.5	35.8	18.9	1.2	46.2	-	0
9	23	0.6	0.6	52.6	45.9	2.3	50.1	-	0
9	24	0.6	0.6	29.2	26.6	2.3	49.8	-	0
9	25	4.5	4.5	0.0	0.0	0.2	45.2	-	0
9	26	5.1	5.1	0.0	0.0	0.0	40.1	-	1
9	27	4.7	4.7	0.0	0.0	0.0	35.4	-	1
9	28	3.3	3.3	0.0	0.0	0.0	32.2	-	1
9	29	5.1	5.1	1.8	0.0	0.0	28.9	-	1
9	30	4.1	3.9	0.0	0.0	0.0	25.0	-	1
10	1	3.5	0.0	0.0	0.0	0.0	25.0	-	1
10	2	4.7	0.0	17.8	3.9	0.0	38.8	-	1
10	3	4.3	4.3	0.0	0.0	0.0	34.6	-	1
10	4	4.1	4.1	0.0	0.0	0.0	30.5	-	1
10	5	4.3	4.3	0.0	0.0	0.0	26.2	-	1
10	6	5.9	1.2	0.0	0.0	0.0	25.0	-	1
10	7	3.7	0.0	0.0	0.0	0.0	25.0	-	1
10	8	4.7	0.0	0.0	0.0	0.0	25.0	-	1
10	9	4.7	0.0	0.3	0.0	0.0	25.3	-	1
10	10	5.1	0.3	0.0	0.0	0.0	25.0	-	1
10	11	6.3	0.0	0.0	0.0	0.0	25.0	-	1
10	12	3.9	0.0	0.0	0.0	0.0	25.0	-	1
10	13	4.9	0.0	0.0	0.0	0.0	25.0	-	1
10	14	4.7	0.0	0.0	0.0	0.0	25.0	-	1
10	15	4.7	0.0	0.0	0.0	0.0	25.0	-	1
10	16	4.1	0.0	0.0	0.0	0.0	25.0	-	1
10	17	5.3	0.0	2.8	0.0	0.0	27.8	-	1
10	18	4.3	2.8	0.0	0.0	0.0	25.0	-	1
10	19	5.5	0.0	2.8	0.0	0.0	27.8	-	1
10	20	2.4	2.4	1.5	0.0	0.0	26.9	-	1
10	21	2.4	1.9	16.3	3.2	0.0	38.1	-	1
10	22	1.8	1.8	0.5	0.0	0.0	36.8	-	1
10	23	4.1	4.1	0.0	0.0	0.0	32.7	-	1
10	24	4.7	4.7	0.0	0.0	0.0	28.0	-	1
10	25	4.7	3.0	0.0	0.0	0.0	25.0	-	1
10	26	4.1	0.0	0.0	0.0	0.0	25.0	-	1
10	27	4.5	0.0	0.0	0.0	0.0	25.0	-	1
10	28	5.3	0.0	0.0	0.0	0.0	25.0	-	1
10	29	2.0	0.0	2.5	0.0	0.0	27.5	-	1
10	30	4.7	2.5	1.0	0.0	0.0	26.0	-	1
10	31	1.8	1.0	0.0	0.0	0.0	25.0	-	1
11	1	4.5	0.0	0.0	0.0	0.0	25.0	-	1
11	2	3.5	0.0	0.0	0.0	0.0	25.0	-	1
11	3	4.9	0.0	0.0	0.0	0.0	25.0	-	1
11	4	4.3	0.0	0.0	0.0	0.0	25.0	-	1
11	5	4.7	0.0	0.0	0.0	0.0	25.0	-	1
11	6	3.5	0.0	9.7	0.6	0.0	34.1	-	1
11	7	3.3	3.3	0.5	0.0	0.0	31.3	-	1
11	8	3.3	3.3	0.0	0.0	0.0	28.1	-	1
11	9	2.2	2.2	1.8	0.0	0.0	27.6	-	1
11	10	4.1	2.6	0.0	0.0	0.0	25.0	-	1
11	11	3.9	0.0	0.0	0.0	0.0	25.0	-	1
11	12	4.1	0.0	0.0	0.0	0.0	25.0	-	1
11	13	4.3	0.0	0.0	0.0	0.0	25.0	-	1
11	14	4.7	0.0	0.0	0.0	0.0	25.0	-	1
11	15	4.7	0.0	0.0	0.0	0.0	25.0	-	1
11	16	3.9	0.0	0.0	0.0	0.0	25.0	-	1
11	17	4.3	0.0	0.0	0.0	0.0	25.0	-	1
11	18	5.3	0.0	0.0	0.0	0.0	25.0	-	1
11	19	5.3	0.0	0.0	0.0	0.0	25.0	-	1
11	20	4.3	0.0	0.0	0.0	0.0	25.0	-	1
11	21	4.1	0.0	0.0	0.0	0.0	25.0	-	1
11	22	3.9	0.0	0.0	0.0	0.0	25.0	-	1
11	23	5.1	0.0	0.0	0.0	0.0	25.0	-	1
11	24	4.9	0.0	0.0	0.0	0.0	25.0	-	1
11	25	4.3	0.0	0.0	0.0	0.0	25.0	-	1
11	26	4.1	0.0	0.0	0.0	0.0	25.0	-	1

3. Tulu et al. (1974) modified model daily summary output file

The next example shows the output of daily soil moisture computations and definition of a working-non-working day for Tulu et al. (1974) modified model. As in the previous example the first three columns present the date. Potential evapotranspiration, actual evapotranspiration from layers 1, 2, and 3, daily rainfall, runoff, drainage from each layer, and soil moisture content for each layer and for the 150 mm of soil are presented in the following columns. The last two columns were explained in the previous example.

OUTPUT RUNNING TULU ET. AL. MODEL
 PRINT OUTPUT FOR C:\QB45\EXATUL.DAY
 USING WEATHER DATA INPUTFILE C:\QB45\A.IN

CROP VEGETABLES
 INITIAL MOISTURE CONTENT 30 mm/150mm

INITIAL MOISTURE CONTENT LAYER 1 : 6 mm/30mm
 INITIAL MOISTURE CONTENT LAYER 2 : 9 mm/45mm
 INITIAL MOISTURE CONTENT LAYER 3 : 15 mm/75mm

SELECTIONS FOR THIS RUN:

1. WILTING POINT 25 mm/150mm
2. FIELD CAPACITY 45 mm/150mm
3. INITIAL MOISTURE CONTENT 30 mm/150mm)
4. RUNOFF COEFFICIENT: 1
5. DRAINAGE COEFFICIENT FOR LAYER 1: 1
6. DRAINAGE COEFFICIENT FOR LAYER 2: 1
7. DRAINAGE COEFFICIENT FOR LAYER 3: 1
- SOIL MOISTURE PERCENT TO AFFECT OPERATIONS:
8. FOR TILLAGE OPERATIONS LAYER 1 (95 %)
9. FOR TILLAGE OPERATIONS LAYER 2 (95 %)
10. FOR TILLAGE OPERATIONS LAYER 3 (98.5 %)
11. FOR NON TILLAGE OPERATIONS LAYER 1 (98 %)
12. FOR NON TILLAGE OPERATIONS LAYER 2 (99 %)
13. FOR NON TILLAGE OPERATIONS LAYER 3 (99 %)

DATE	PET	E	T	RN	RO	DRAINAGE	SOIL	MOISTURE	WORK
MON DAY:	FROM LAYER				(FROM-TO)	LAYER	TOT:		
:	1 2 3				1-2-3-4	1 2 3	TL NTL		
1989									
7 1	6.1	1.0	0.9	0.1	0	0	0.0	0.0	5.0 8.1 14.9 28.0 1 -
7 2	6.1	0.0	0.6	0.1	0	0	0.0	0.0	5.0 7.5 14.8 27.3 1 -
7 3	4.5	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 14.7 27.2 1 -
7 4	5.3	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 14.6 27.1 1 -
7 5	5.5	0.0	0.0	0.1	11	1	5.6	0.0	9.0 13.1 14.5 36.6 0 -
7 6	6.9	1.4	1.0	0.1	7	1	5.1	3.7	9.0 13.5 18.1 40.6 0 -
7 7	4.3	0.8	0.6	0.1	0	0	0.0	0.0	8.2 12.9 18.0 39.1 0 -
7 8	5.9	1.2	0.8	0.1	0	0	0.0	0.0	7.0 12.0 17.9 37.0 1 -
7 9	5.5	1.1	0.8	0.1	1	0	0.0	0.0	6.7 11.2 17.8 35.7 1 -
7 10	4.9	1.0	0.7	0.1	0	0	0.0	0.0	5.7 10.5 17.8 34.0 1 -
7 11	6.1	0.7	0.9	0.1	0	0	0.0	0.0	5.0 9.7 17.6 32.3 1 -
7 12	6.1	0.0	0.9	0.1	2	0	0.0	0.0	6.5 8.8 17.5 32.8 1 -
7 13	4.9	1.0	0.7	0.1	1	0	0.0	0.0	6.8 8.1 17.4 32.4 1 -
7 14	4.9	1.0	0.6	0.1	0	0	0.0	0.0	5.9 7.5 17.4 30.7 1 -
7 15	6.7	0.9	0.0	0.1	0	0	0.0	0.0	5.0 7.5 17.2 29.7 1 -
7 16	6.5	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 17.1 29.6 1 -
7 17	6.7	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 17.0 29.5 1 -
7 18	6.1	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 16.9 29.4 1 -
7 19	6.1	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 16.8 29.3 1 -
7 20	6.1	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 16.7 29.2 1 -
7 21	6.1	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 16.6 29.1 1 -
7 22	6.3	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 16.4 28.9 1 -
7 23	6.5	0.0	0.0	0.1	7	0	2.9	0.0	9.0 10.4 16.3 35.7 0 -
7 24	6.5	1.3	0.9	0.1	0	0	0.0	0.0	7.7 9.4 16.2 33.3 1 -
7 25	6.3	1.2	0.9	0.1	2	0	0.0	0.0	8.2 8.5 16.1 32.9 1 -
7 26	6.1	1.2	0.9	0.1	0	0	0.0	0.0	7.0 7.6 16.0 30.7 1 -
7 27	5.7	1.1	0.1	0.1	0	0	0.0	0.0	5.9 7.5 15.9 29.3 1 -
7 28	4.1	0.8	0.0	0.1	0	0	0.0	0.0	5.1 7.5 15.8 28.4 1 -
7 29	5.7	0.1	0.0	0.1	0	0	0.0	0.0	5.0 7.5 15.7 28.2 1 -
7 30	2.0	0.0	0.0	0.0	0	0	0.0	0.0	5.0 7.5 15.7 28.2 1 -
7 31	2.0	0.0	0.0	0.0	0	0	0.0	0.0	5.0 7.5 15.6 28.1 1 -
8 1	5.9	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 15.5 28.0 1 -
8 2	6.7	0.0	0.0	0.1	0	0	0.0	0.0	5.0 7.5 15.4 27.9 1 -
8 3	7.7	0.0	0.0	0.1	9	1	4.5	0.0	9.0 12.0 15.3 36.2 0 -
8 4	5.7	1.1	0.8	0.1	0	0	0.0	0.0	7.9 11.2 15.2 34.2 1 -
8 5	6.3	1.2	0.9	0.1	0	0	0.0	0.0	6.6 10.3 15.1 31.9 1 -
8 6	5.9	1.2	0.8	0.1	10	1	5.1	1.0	9.0 13.5 15.9 38.4 0 -
8 7	5.7	1.1	0.8	0.1	0	0	0.0	0.0	7.9 12.7 15.8 36.4 1 -
8 8	4.9	1.0	0.7	0.1	3	0	1.0	0.0	9.0 12.9 15.8 37.7 0 -
8 9	5.9	1.2	0.8	0.1	0	0	0.0	0.0	7.8 12.1 15.6 35.6 1 -
8 10	6.5	1.3	0.9	0.1	0	0	0.0	0.0	6.5 11.1 15.5 33.2 1 -
8 11	4.5	0.9	0.6	0.1	14	3	7.3	4.3	9.0 13.5 19.8 42.3 0 -
8 12	4.7	0.9	0.7	0.1	17	8	7.6	6.9	9.0 13.5 22.5 45.0 0 -
8 13	5.3	1.0	0.8	0.1	0	0	0.0	0.0	8.0 12.7 22.4 43.1 0 -
8 14	5.9	1.2	0.8	0.1	0	0	0.0	0.0	6.8 11.9 22.3 41.0 0 -
8 15	6.1	1.2	0.9	0.1	0	0	0.0	0.0	5.6 11.0 22.2 38.8 0 -
8 16	6.3	0.6	0.9	0.1	0	0	0.0	0.0	5.0 10.1 22.1 37.2 1 -
8 17	4.3	0.0	0.6	0.1	1	0	0.0	0.0	5.8 9.5 22.0 37.3 1 -
8 18	3.5	0.7	0.5	0.1	6	1	1.9	0.0	9.0 10.9 21.9 41.8 0 -
8 19	6.5	1.3	0.9	0.1	10	3	5.9	2.3	9.0 13.5 22.5 45.0 0 -
8 20	5.7	1.1	0.8	0.1	1	0	0.1	0.0	9.0 12.8 22.4 44.2 0 -

8	21	2.8	0.6	0.4	0.1	2	0	1.0	0.0	0.0	9.0	13.4	22.3	44.7	0	-
8	22	6.1	1.2	0.9	0.1	12	5	5.5	4.5	4.2	9.0	13.5	22.5	45.0	0	-
8	23	2.8	0.6	0.4	0.1	0	0	0.0	0.0	0.0	8.4	13.1	22.4	44.0	0	-
8	24	4.1	0.8	0.6	0.1	19	11	6.5	5.5	5.4	9.0	13.5	22.5	45.0	0	-
8	25	4.7	0.9	0.7	0.1	15	8	5.9	5.2	5.1	9.0	13.5	22.5	45.0	0	-
8	26	6.1	1.2	0.9	0.1	8	2	4.2	3.3	3.2	9.0	13.5	22.5	45.0	0	-
8	27	6.3	1.2	0.9	0.1	0	0	0.0	0.0	0.0	7.8	12.6	22.4	42.7	0	-
8	28	2.6	0.5	0.4	0.0	0	0	0.0	0.0	0.0	7.2	12.2	22.3	41.8	0	-
8	29	3.7	0.7	0.5	0.1	13	5	5.2	3.4	3.1	9.0	13.5	22.5	45.0	0	-
8	30	2.4	0.5	0.4	0.0	8	3	4.7	4.3	4.3	9.0	13.5	22.5	45.0	0	-
8	31	5.5	1.1	0.8	0.1	0	0	0.0	0.0	0.0	7.9	12.7	22.4	43.0	0	-
9	1	4.9	1.0	0.7	0.1	0	0	0.0	0.0	0.0	6.9	12.0	22.3	41.3	0	-
9	2	5.7	1.1	0.8	0.1	0	0	0.0	0.0	0.0	5.8	11.2	22.2	39.2	0	-
9	3	5.3	0.8	0.6	0.1	1	0	0.0	0.0	0.0	6.3	10.4	22.1	38.8	1	-
9	4	3.9	0.8	0.6	0.1	0	0	0.0	0.0	0.0	5.5	9.9	22.0	37.4	1	-
9	5	6.5	0.5	0.9	0.1	0	0	0.0	0.0	0.0	5.0	8.9	21.9	35.9	1	-
9	6	6.7	0.0	1.0	0.1	0	0	0.0	0.0	0.0	5.0	8.0	21.8	34.8	1	-
9	7	5.3	0.0	0.5	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.7	34.2	1	-
9	8	6.5	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.6	34.1	1	-
9	9	6.5	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.5	34.0	1	-
9	10	4.9	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.4	33.9	1	-
9	11	4.9	0.0	0.0	0.1	31	17	10.5	4.5	3.3	9.0	13.5	22.5	45.0	0	-
9	12	3.5	0.7	0.5	0.1	0	0	0.0	0.0	0.0	8.3	13.0	22.4	43.8	0	-
9	13	4.1	0.8	0.6	0.1	0	0	0.0	0.0	0.0	7.5	12.4	22.4	42.3	0	-
9	14	5.5	1.1	0.8	0.1	0	0	0.0	0.0	0.0	6.4	11.6	22.3	40.3	0	-
9	15	3.7	0.7	0.5	0.1	4	0	0.4	0.0	0.0	9.0	11.5	22.2	42.7	0	-
9	16	4.9	1.0	0.7	0.1	0	0	0.0	0.0	0.0	8.0	10.8	22.1	40.9	1	-
9	17	5.3	1.0	0.8	0.1	0	0	0.0	0.0	0.0	7.0	10.0	22.0	39.0	1	-
9	18	4.1	0.8	0.6	0.1	8	1	3.6	0.0	0.0	9.0	13.0	21.9	44.0	0	-
9	19	7.9	1.6	1.1	0.1	10	3	5.1	3.5	2.8	9.0	13.5	22.5	45.0	0	-
9	20	3.9	0.8	0.6	0.1	0	0	0.0	0.0	0.0	8.2	12.9	22.4	43.6	0	-
9	21	4.9	1.0	0.7	0.1	9	3	4.2	3.0	2.8	9.0	13.5	22.5	45.0	0	-
9	22	3.5	0.7	0.5	0.1	36	28	7.4	6.9	6.8	9.0	13.5	22.5	45.0	0	-
9	23	0.6	0.1	0.1	0.0	53	45	7.4	7.3	7.3	9.0	13.5	22.5	45.0	0	-
9	24	0.6	0.1	0.1	0.0	29	22	6.8	6.8	6.7	9.0	13.5	22.5	45.0	0	-
9	25	4.5	0.9	0.6	0.1	0	0	0.0	0.0	0.0	8.1	12.9	22.4	43.4	0	-
9	26	5.1	1.0	0.7	0.1	0	0	0.0	0.0	0.0	7.1	12.1	22.3	41.6	0	-
9	27	4.7	0.9	0.7	0.1	0	0	0.0	0.0	0.0	6.2	11.5	22.2	39.9	0	-
9	28	3.3	0.6	0.5	0.1	0	0	0.0	0.0	0.0	5.5	11.0	22.2	38.7	0	-
9	29	5.1	0.5	0.7	0.1	2	0	0.0	0.0	0.0	6.8	10.3	22.1	39.1	1	-
9	30	4.1	0.8	0.6	0.1	0	0	0.0	0.0	0.0	6.0	9.7	22.0	37.7	1	-
10	1	3.5	0.9	0.7	0.1	0	0	0.0	0.0	0.0	5.0	9.0	21.9	35.9	1	-
10	2	4.7	0.0	0.9	0.1	18	7	7.2	1.7	1.0	9.0	13.5	22.5	45.0	0	-
10	3	4.3	1.2	0.9	0.1	0	0	0.0	0.0	0.0	7.8	12.6	22.4	42.9	0	-
10	4	4.1	1.1	0.8	0.1	0	0	0.0	0.0	0.0	6.7	11.8	22.3	40.8	0	-
10	5	4.3	1.2	0.9	0.1	0	0	0.0	0.0	0.0	5.5	11.0	22.2	38.7	0	-
10	6	5.9	0.5	1.2	0.1	0	0	0.0	0.0	0.0	5.0	9.8	22.0	36.8	1	-
10	7	3.7	0.0	0.7	0.1	0	0	0.0	0.0	0.0	5.0	9.1	21.9	36.0	1	-
10	8	4.7	0.0	0.9	0.1	0	0	0.0	0.0	0.0	5.0	8.1	21.8	35.0	1	-
10	9	4.7	0.0	0.6	0.1	0	0	0.0	0.0	0.0	5.3	7.5	21.7	34.5	1	-
10	10	5.1	0.3	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.6	34.1	1	-
10	11	6.3	0.0	0.0	0.2	0	0	0.0	0.0	0.0	5.0	7.5	21.4	33.9	1	-
10	12	3.9	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.3	33.8	1	-
10	13	4.9	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.2	33.7	1	-
10	14	4.7	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.1	33.6	1	-
10	15	4.7	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.0	33.5	1	-
10	16	4.1	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	20.9	33.4	1	-
10	17	5.3	0.0	0.0	0.1	3	0	0.0	0.0	0.0	7.8	7.5	20.7	36.0	1	-
10	18	4.3	1.2	0.0	0.1	0	0	0.0	0.0	0.0	6.6	7.5	20.6	34.8	1	-
10	19	5.5	1.5	0.0	0.1	3	0	0.0	0.0	0.0	7.9	7.5	20.5	35.9	1	-
10	20	2.4	0.7	0.0	0.1	2	0	0.0	0.0	0.0	8.8	7.5	20.4	36.7	0	-
10	21	2.4	0.7	0.0	0.1	16	6	9.4	3.4	1.3	9.0	13.5	22.5	45.0	0	-
10	22	1.8	0.5	0.4	0.0	1	0	0.0	0.0	0.0	9.0	13.1	22.5	44.6	0	-
10	23	4.1	1.1	0.8	0.1	0	0	0.0	0.0	0.0	7.9	12.3	22.4	42.6	0	-
10	24	4.7	1.3	0.9	0.1	0	0	0.0	0.0	0.0	6.6	11.4	22.2	40.2	0	-
10	25	4.7	1.3	0.9	0.1	0	0	0.0	0.0	0.0	5.3	10.5	22.1	37.9	1	-
10	26	4.1	0.3	0.8	0.1	0	0	0.0	0.0	0.0	5.0	9.6	22.0	36.7	1	-
10	27	4.5	0.0	0.9	0.1	0	0	0.0	0.0	0.0	5.0	8.8	21.9	35.7	1	-
10	28	5.3	0.0	1.1	0.1	0	0	0.0	0.0	0.0	5.0	7.7	21.8	34.5	1	-
10	29	2.0	0.0	0.2	0.1	3	0	0.0	0.0	0.0	7.5	7.5	21.7	36.8	1	-
10	30	4.7	1.3	0.0	0.1	1	0	0.0	0.0	0.0	7.3	7.5	21.6	36.4	1	-
10	31	1.8	0.5	0.0	0.0	0	0	0.0	0.0	0.0	6.8	7.5	21.6	35.8	1	-
11	1	4.5	1.7	0.0	0.2	0	0	0.0	0.0	0.0	5.0	7.5	21.4	34.0	1	-
11	2	3.5	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.3	33.8	1	-
11	3	4.9	0.0	0.0	0.2	0	0	0.0	0.0	0.0	5.0	7.5	21.1	33.6	1	-
11	4	4.3	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	21.0	33.5	1	-
11	5	4.7	0.0	0.0	0.2	0	0	0.0	0.0	0.0	5.0	7.5	20.8	33.3	1	-
11	6	3.5	0.0	0.0	0.1	10	1	4.2	0.0	0.0	9.0	11.7	20.7	41.4	0	-
11	7	3.3	1.3	0.9	0.1	1	0	0.0	0.0	0.0	8.3	10.8	20.6	39.6	1	-
11	8	3.3	1.3	0.9	0.1	0	0	0.0	0.0	0.0	7.0	9.9	20.5	37.3	1	-
11	9	2.2	0.9	0.6	0.1	2	0	0.0	0.0	0.0	7.9	9.3	20.4	37.6	1	-
11	10	4.1	1.6	1.1	0.1	0	0	0.0	0.0	0.0	6.4	8.1	20.2	34.7	1	-
11	11	3.9	1.4	0.6	0.1	0	0	0.0	0.0	0.0	5.0	7.5	20.1	32.6	1	-
11	12	4.1	0.0	0.0	0.1	0	0	0.0	0.0	0.0	5.0	7.5	20.0	32.5	1	-

4. Babeir et al. (1986) modified model daily summary output file.

Output of daily soil moisture computations and definition of a working-non-working day for Babeir et al. (1986) modified model is presented in the next example. As in the previous example the first three columns present the date. Potential evapotranspiration, actual evapotranspiration from layers 1, 2, and 3, daily rainfall, runoff, drainage from each layer, diffusion between layers 1 and 2, 2 and 3, and 3 and 4, and soil moisture content for each layer and for the 150 mm of soil are presented in the following columns. When diffusion is negative the water moves to the deeper layer from the upper layer. When it is positive then vice versa. The last two columns were explained in the second example.

PRINT OUTPUT FOR C:\QB45\EXAMPLE.DAY

.....BABEIR MODEL.....

DATE: 06-23-1993 TIME: 21:43:51
USING WEATHER DATA INPUTFILE A:A.INCROP VEGETABLES
INITIAL MOISTURE CONTENT : 30 mm/150mm
INITIAL MOISTURE CONTENT LAYER 1 : 9 mm/50mm
INITIAL MOISTURE CONTENT LAYER 2 : 9 mm/50mm
INITIAL MOISTURE CONTENT LAYER 3 : 12 mm/50mm
INITIAL MOISTURE CONTENT LAYER 4 : 12 mm/50mm
FIELD CAPACITY: 45 FIELD CAPACITY LAYERS: 15
WILTING POINT: 25 WILTING POINT LAYERS: 8.33
DRAINAGE COEFFICIENT = 1
DIFFUSION COEFFICIENT = 1
RUNOFF COEFFICIENT = 1
PERCENT FOR TILLAGE OPERATIONS (95 95 98.5 %)
PERCENT FOR NO TILLAGE OPERATIONS (98 99 99 %)

MN/DAY	PET	ET		RAIN	RO	DRAINAGE			DIFFUSION			SOIL MOISTURE				WORK		
		1	2			3	1-2	2-3	3-4	1	2	3	TOT	T	NT			
1989																		
7	1	6.1	0.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0	3.6	3.7	8.3	11.9	12.0	32.2	1 -	
7	2	6.1	0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.0	2.7	3.6	0.0	11.0	11.9	8.3	31.3	1 -
7	3	4.5	0.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.1	-1.8	-1.8	11.3	8.3	8.3	27.9	1 -
7	4	5.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.9	-1.9	-0.1	8.3	8.3	10.2	26.8	1 -
7	5	5.5	0.0	0.0	0.1	10.7	1.0	3.0	0.0	0.0	-3.7	-4.9	-4.7	11.3	10.1	10.3	31.6	1 -
7	6	6.9	1.3	1.0	0.1	7.1	0.3	1.8	0.0	0.0	-4.1	-4.9	0.0	10.9	10.1	15.0	36.0	0 -
7	7	4.3	0.8	0.6	0.1	0.0	0.0	0.0	0.0	0.0	-0.6	4.8	4.9	9.5	14.9	15.0	39.5	0 -
7	8	5.9	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	5.7	6.5	1.7	14.1	14.9	10.1	39.1	0 -
7	9	5.5	1.1	0.8	0.1	0.8	0.0	0.0	0.0	0.0	0.3	-3.8	-5.4	14.1	10.0	8.4	32.5	1 -
7	10	4.9	0.9	0.7	0.1	0.0	0.0	0.0	0.0	0.0	-3.9	-4.9	0.6	9.3	8.3	13.8	31.5	1 -
7	11	6.1	1.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	5.4	4.9	8.3	13.7	13.2	35.2	1 -
7	12	6.1	0.0	0.9	0.1	1.5	0.0	0.0	0.0	0.0	3.0	3.2	-1.5	12.8	13.1	8.3	34.3	1 -
7	13	4.9	0.9	0.7	0.0	1.3	0.0	0.0	0.0	0.0	-0.8	-4.8	-3.3	12.4	8.3	9.9	30.6	1 -
7	14	4.9	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-3.1	-1.7	1.7	8.3	9.8	13.2	31.3	1 -
7	15	6.7	0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.5	4.7	3.1	8.8	13.1	11.5	33.4	1 -
7	16	6.5	0.5	0.9	0.1	0.0	0.0	0.0	0.0	0.0	3.8	3.0	0.0	12.1	11.3	8.3	31.8	1 -
7	17	6.7	1.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	-2.5	-2.5	10.4	8.3	8.3	27.1	1 -
7	18	6.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-0.9	1.6	8.3	8.3	10.9	27.5	1 -
7	19	6.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.9	8.3	10.8	9.2	28.3	1 -
7	20	6.1	0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.0	1.6	0.8	0.0	9.9	9.1	8.3	27.4	1 -
7	21	6.1	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	-0.4	-0.4	8.3	8.3	8.3	25.0	1 -
7	22	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	8.3	8.3	8.7	25.4	1 -
7	23	6.5	0.0	0.0	0.1	7.1	0.1	0.3	0.0	0.0	-6.3	-6.4	-6.7	8.7	8.6	8.3	25.6	1 -
7	24	6.5	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	8.3	8.3	15.0	31.7	0 -
7	25	6.3	0.0	0.0	0.1	1.8	0.0	0.0	0.0	0.0	-1.8	4.8	-1.8	8.3	14.9	8.3	31.6	0 -
7	26	6.1	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0	1.8	14.0	8.3	10.1	32.5	1 -
7	27	5.7	1.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-4.6	-2.9	-4.6	8.3	10.0	8.3	26.7	1 -
7	28	4.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	4.6	9.4	8.3	12.9	30.7	1 -
7	29	5.7	1.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-0.0	4.5	-0.0	8.3	12.8	8.3	29.5	1 -
7	30	2.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	12.6	8.3	8.3	29.2	1 -
7	31	2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.8	-3.8	-3.8	8.3	8.3	8.3	25.0	1 -
1990																		
8	1	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	8.3	8.3	12.2	28.8	1 -	
8	2	6.7	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	8.3	12.0	8.3	28.7	1 -
8	3	7.7	0.0	1.1	0.0	9.1	0.7	1.8	0.0	0.0	-2.2	-6.7	-6.7	12.8	8.3	8.3	29.5	1 -
8	4	5.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.4	-3.4	3.3	8.3	8.3	15.0	31.7	0 -
8	5	6.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.6	3.4	8.3	14.9	11.7	34.9	0 -
8	6	5.9	0.0	0.8	0.1	9.7	1.6	1.4	0.5	0.0	0.0	-2.9	-6.7	15.0	12.1	8.3	35.4	0 -
8	7	5.7	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-2.6	-5.6	1.1	11.3	8.3	15.0	34.6	0 -
8	8	4.9	0.9	0.0	0.1	3.0	0.0	0.0	0.0	0.0	-5.1	1.5	0.5	8.3	14.9	13.9	37.2	0 -
8	9	5.9	0.0	0.8	0.1	0.0	0.0	0.0	0.0	0.0	5.8	5.5	5.1	14.1	13.8	13.4	41.3	1 -
8	10	6.5	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.4	-4.5	12.9	13.3	8.3	34.5	1 -
8	11	4.5	0.9	0.6	0.0	14.0	3.6	7.4	5.0	0.0	0.0	-1.6	-2.2	15.0	13.4	12.8	41.2	0 -
8	12	4.7	0.9	0.7	0.1	16.5	7.5	8.1	5.8	3.5	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	13	5.3	1.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.9	-2.5	14.3	14.9	11.5	40.6	0 -
8	14	5.9	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	1.0	-1.8	0.9	14.1	11.4	14.0	39.4	1 -
8	15	6.1	1.2	0.9	0.1	0.0	0.0	0.0	0.0	0.0	-2.4	1.0	0.2	10.5	13.9	13.1	37.5	1 -
8	16	6.3	1.2	0.9	0.1	0.0	0.0	0.0	0.0	0.0	3.7	3.7	3.6	13.0	13.0	12.9	38.9	1 -
8	17	4.3	0.8	0.6	0.1	0.8	0.0	0.0	0.0	0.0	-0.5	-0.1	-3.6	12.4	12.8	9.3	34.5	1 -
8	18	3.5	0.7	0.5	0.1	6.3	0.3	2.8	0.1	0.0	0.0	-5.7	-2.1	15.0	9.3	12.9	37.3	0 -
8	19	6.5	1.3	0.9	0.1	10.2	2.0	6.9	0.4	0.0	0.0	-1.8	0.0	15.0	13.2	15.0	43.2	0 -
8	20	5.7	1.1	0.8	0.1	1.3	0.0	0.2	0.0	0.0	-2.4	-0.1	0.0	12.6	14.9	15.0	42.5	0 -
8	21	2.8	0.5	0.4	0.0	1.5	0.0	0.0	0.0	0.0	1.0	1.4	1.4	14.5	15.0	15.0	44.5	0 -
8	22	6.1	1.2	0.9	0.1	12.2	5.4	5.1	4.2	4.1	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	23	2.8	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	-2.1	14.6	15.0	12.3	41.9	0 -
8	24	4.1	0.8	0.6	0.1	19.3	10.2	7.9	7.3	4.5	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	25	4.7	0.9	0.7	0.1	14.7	7.9	5.9	5.2	5.1	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	26	6.1	1.2	0.9	0.1	7.9	2.5	4.2	3.4	3.3	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	27	6.3	1.2	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.3	1.1	-2.0	14.1	14.9	11.7	40.7	0 -
8	28	2.6	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	-1.9	0.2	14.5	11.7	13.8	40.0	0 -
8	29	3.7	0.7	0.5	0.1	12.7	4.4	7.1	3.3	2.0	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	30	2.4	0.5	0.3	0.0	8.4	3.3	4.7	4.3	4.3	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0 -
8	31	5.5	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.3	1.0	-3.2	14.2	14.9	10.7	39.9	0 -

9	1	4.9	0.9	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.9	-2.7	0.7	14.2	10.6	13.9	38.8	1	-
9	2	5.7	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	-3.3	0.7	0.2	9.8	13.8	13.3	37.0	1	-
9	3	5.3	1.0	0.7	0.1	1.3	0.0	0.0	0.0	0.0	3.0	3.1	3.0	13.1	13.2	13.1	39.4	1	-
9	4	3.9	0.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.7	-2.3	12.7	13.1	10.1	35.8	1	-
9	5	6.5	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.7	-1.4	1.0	12.1	10.0	12.4	34.5	1	-
9	6	6.7	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	-1.8	1.4	0.6	9.0	12.2	11.4	32.7	1	-
9	7	5.3	0.7	0.7	0.1	0.0	0.0	0.0	0.0	0.0	3.2	3.0	2.5	11.5	11.3	10.9	33.7	1	-
9	8	6.5	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.5	-1.9	10.4	10.7	8.3	29.5	1	-
9	9	6.5	1.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.7	-0.8	1.1	9.8	8.3	10.3	28.4	1	-
9	10	4.9	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-0.6	1.3	0.3	8.3	10.2	9.2	27.7	1	-
9	11	4.9	0.0	0.7	0.1	31.5	13.711	1.1	5.6	0.0	0.0	-0.3	-6.1	15.0	14.7	8.9	38.6	0	-
9	12	3.5	0.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-5.5	0.7	14.2	8.8	15.0	38.0	0	-
9	13	4.1	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	-5.1	1.5	0.9	8.3	14.9	14.3	37.6	0	-
9	14	5.5	0.0	0.8	0.1	0.0	0.0	0.0	0.0	0.0	5.8	5.9	5.1	14.2	14.2	13.4	41.8	1	-
9	15	3.7	0.7	0.5	0.1	3.8	0.2	2.1	0.8	0.0	0.0	-0.8	-6.7	15.0	14.2	8.3	37.5	0	-
9	16	4.9	0.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	-5.7	0.9	13.5	8.3	15.0	36.8	0	-
9	17	5.3	1.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-4.1	2.4	1.6	8.3	14.9	14.1	37.3	0	-
9	18	4.1	0.0	0.6	0.1	7.6	1.1	0.0	0.0	0.0	-0.5	-0.9	-2.4	14.3	14.0	12.5	40.8	0	-
9	19	7.9	1.5	1.1	0.1	10.2	2.6	5.4	3.3	0.6	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0	-
9	20	3.9	0.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.3	14.5	14.9	14.5	43.9	0	-
9	21	4.9	0.9	0.7	0.1	8.6	2.8	4.4	3.6	3.1	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0	-
9	22	3.5	0.7	0.5	0.1	35.8	27.8	7.4	6.9	6.8	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0	-
9	23	0.6	0.1	0.1	0.0	52.6	45.1	7.4	7.3	7.3	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0	-
9	24	0.6	0.1	0.1	0.0	29.2	22.2	6.8	6.8	6.7	0.0	0.0	0.0	15.0	15.0	15.0	45.0	0	-
9	25	4.5	0.9	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.8	6.0	14.4	14.9	8.3	37.6	0	-
9	26	5.1	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.8	-5.1	0.9	14.2	8.3	14.3	36.8	1	-
9	27	4.7	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-5.0	0.9	0.1	8.3	14.2	13.4	35.9	1	-
9	28	3.3	0.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	5.4	5.0	5.0	13.8	13.3	13.3	40.4	1	-
9	29	5.1	1.0	0.7	0.1	1.8	0.0	0.0	0.0	0.0	-1.9	-1.3	-6.2	12.6	13.2	8.3	34.2	1	-
9	30	4.1	0.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	-3.5	2.7	12.7	8.3	14.6	35.5	1	-
10	1	3.5	0.9	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-3.4	2.8	0.1	8.3	14.5	11.8	34.6	0	-
10	2	4.7	0.0	0.9	0.1	17.8	6.2	4.9	3.4	0.2	0.0	0.0	-3.1	15.0	15.0	11.9	41.9	0	-
10	3	4.3	1.2	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.3	-2.1	1.2	14.1	11.8	15.0	40.9	0	-
10	4	4.1	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	-2.1	1.9	0.8	11.0	14.9	13.8	39.7	0	-
10	5	4.3	1.2	0.9	0.1	0.0	0.0	0.0	0.0	0.0	4.3	3.9	3.2	14.0	13.7	13.0	40.8	1	-
10	6	5.9	1.6	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.5	-2.6	12.5	12.9	9.8	35.2	1	-
10	7	3.7	1.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.6	-1.8	0.9	12.2	9.7	12.4	34.3	1	-
10	8	4.7	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	-2.1	1.4	0.7	8.8	12.3	11.5	32.6	1	-
10	9	4.7	0.4	0.9	0.1	0.3	0.0	0.0	0.0	0.0	2.8	2.8	2.3	11.4	11.4	10.9	33.7	1	-
10	10	5.1	1.4	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.4	0.8	-1.4	10.4	10.7	8.6	29.7	1	-
10	11	6.3	1.7	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.8	-0.2	1.3	9.5	8.4	10.0	27.9	1	-
10	12	3.9	1.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	1.5	0.3	8.3	9.9	8.7	26.9	1	-
10	13	4.9	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.1	8.9	8.5	8.4	25.9	1	-
10	14	4.7	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	8.3	25.0	1	-
10	15	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	8.3	25.0	1	-
10	16	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	8.3	25.0	1	-
10	17	5.3	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	-2.8	-2.8	-2.8	8.3	8.3	8.3	25.0	1	-
10	18	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	8.3	8.3	11.1	27.8	1	-
10	19	5.5	0.0	0.0	0.1	2.8	0.0	0.0	0.0	0.0	-2.8	-0.1	-2.8	8.3	11.0	8.3	27.7	1	-
10	20	2.4	0.0	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.6	-1.5	1.3	10.5	8.3	11.1	30.0	1	-
10	21	2.4	0.7	0.0	0.1	16.3	4.0	7.1	0.4	0.0	0.0	-3.5	-5.1	15.0	11.5	9.9	36.3	0	-
10	22	1.8	0.5	0.4	0.0	0.5	0.0	0.0	0.0	0.0	-3.9	-5.2	0.0	11.1	9.8	15.0	35.9	0	-
10	23	4.1	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	-1.0	4.9	5.0	9.0	14.9	15.0	38.9	0	-
10	24	4.7	0.7	0.9	0.1	0.0	0.0	0.0	0.0	0.0	5.6	6.5	1.6	14.0	14.9	10.0	38.8	0	-
10	25	4.7	1.3	0.9	0.1	0.0	0.0	0.0	0.0	0.0	1.3	-2.8	-4.3	13.9	9.9	8.3	32.1	1	-
10	26	4.1	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-3.8	-4.5	-0.2	9.0	8.3	12.7	30.1	1	-
10	27	4.5	0.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	4.2	4.5	8.3	12.6	12.8	33.7	1	-
10	28	5.3	0.0	1.1	0.1	0.0	0.0	0.0	0.0	0.0	3.2	4.4	0.0	11.5	12.7	8.3	32.5	1	-
10	29	2.0	0.6	0.4	0.0	2.5	0.0	0.0	0.0	0.0	-1.2	-5.2	-5.2	12.3	8.3	8.3	29.0	1	-
10	30	4.7	1.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	-3.7	-3.7	1.5	8.3	8.3	13.5	30.2	1	-
10	31	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	3.7	8.3	13.4	12.0	33.8	1	-
11	1	4.5	0.0	1.1	0.1	0.0	0.0	0.0	0.0	0.0	4.0	3.6	0.0	12.4	11.9	8.3	32.6	1	-
11	2	3.5	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-2.9	-2.9	11.1	8.3	8.3	27.7	1	-
11	3	4.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	-1.1	1.8	8.3	8.3	11.2	27.9	1	-
11	4	4.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.8	1.1	8.3	11.1	9.5	28.9	1	-
11	5	4.7	0.0	1.1	0.1	0.0	0.0	0.0	0.0	0.0	1.6	1.0	0.0	10.0	9.3	8.3	27.6	1	-
11	6	3.5	1.1	0.8	0.0	9.7	0.6	2.9	0.0	0.0	-3.7	-6.7	-6.7	11.3	8.3	8.3	28.0	1	-
11	7	3.3	1.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0	-2.4	-2.4	4.2	8.3	8.3	15.0	31.7	0	-
11	8	3.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	6.6	2.4	8.3	14.9	10.8	34.0	0	-
11	9	2.2	0.0	0.5	0.1	1.8	0.0	0.0	0.0	0.0	4.3	0.6	-1.8	14.4	10.7	8.3	33.4	0	-
11	10	4.1	1.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.3	-4.7	-2.9	9.7	8.3	10.1	28.2	1	-
11	11	3.9	1.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	1.5	4.6	8.3	10.0	13.0	31.4	1	-
11	12	4.1	0.0	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.7	4.6	0.1	9.0	12.9	8.5	30.4	1	-
11	13	4.3	0.7	1.0	0.1	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	11.9	8.3	8.3	28.5	1	-
11	14	4.7	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.0	-2.0	-2.0	8.3	8.3	8.3	25.0	1	-
11	15	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	8.3	8.3	10.3	27.0	1	-
11	16	3.9	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	8.3	10.2	8.3	26.9		

5. Models common bimonthly summary output file.

The next example is a common bimonthly summary of working days output file for the three modified models. This example lists output from the Hunt model, but the same format was also used for the other models. The first column shows the year. The period of the month is presented in the second column. Number of working days for each field operation for each period is presented in the last columns.

PRINT OUTPUT FILEC:\QB45\EXAMON.BMN BASED ON HUNT MODEL

WEATHER DATA INPUTFILE C:\QB45\A.IN

DATE:06-23-1993 TIME:22:43:06

SELECTIONS FOR THIS RUN ARE:

1. CROPVEGETABLES
2. PERMANENT WILTING POINT 25.0 mm/150mm
3. FIELD CAPACITY 45.0 mm/150mm
4. INITIAL MOISTURE CONTENT 30.0 mm/150mm
5. CRITERION FOR TILLAGE OPERATIONS 80 %
6. CRITERION FOR NON-TILLAGE OPERATIONS .. 95 %

YEAR	PERIOD	----- WORKING DAYS -----	
		TILLAGE	NON TILLAGE
1989	7/1 TO 7/15	--	15
	7/16 TO 7/31	--	16
	8/1 TO 8/15	--	14
	8/16 TO 8/31	--	13
	9/1 TO 9/15	--	14
	9/16 TO 9/30	--	11
	10/1 TO 10/15	--	15
	10/16 TO 10/31	--	16
	11/1 TO 11/15	--	15
	11/16 TO 11/30	--	15
	12/1 TO 12/15	--	15
	12/16 TO 12/31	--	16
1990	1/1 TO 1/15	--	15
	1/16 TO 1/31	--	16
	2/1 TO 2/15	--	15
	2/16 TO 2/28	--	13
	3/1 TO 3/15	--	15
	3/16 TO 3/31	--	16
	4/1 TO 4/15	--	15
	4/16 TO 4/30	--	15
	5/1 TO 5/15	--	15
	5/16 TO 5/31	--	16
	6/1 TO 6/15	--	14
	6/16 TO 6/30	--	13
	7/1 TO 7/15	--	15
	7/16 TO 7/31	--	14
	8/1 TO 8/15	--	15
	8/16 TO 8/31	--	16
	9/1 TO 9/15	--	15
	9/16 TO 9/30	--	13
1991	10/1 TO 10/15	--	8
	10/16 TO 10/31	--	1
	11/1 TO 11/15	--	14
	11/16 TO 11/30	--	15
	12/1 TO 12/15	--	15
	12/16 TO 12/31	--	16
	1/1 TO 1/15	--	15
	1/16 TO 1/31	--	16
	2/1 TO 2/15	--	15
	2/16 TO 2/28	--	13
	3/1 TO 3/15	--	15
	3/16 TO 3/31	--	15
	4/1 TO 4/15	--	15
	4/16 TO 4/30	--	15

	5/1	TO	5/15	--	15
	5/16	TO	5/31	--	16
	6/1	TO	6/15	--	15
	6/16	TO	6/30	--	15
	7/1	TO	7/15	--	15
	7/16	TO	7/31	--	12
	8/1	TO	8/15	--	15
	8/16	TO	8/31	--	15
	9/1	TO	9/15	--	15
	9/16	TO	9/30	--	13
	10/1	TO	10/15	--	15
	10/16	TO	10/31	--	16
	11/1	TO	11/15	--	11
	11/16	TO	11/30	--	15
	12/1	TO	12/15	--	15
	12/16	TO	12/31	--	16
1992	1/1	TO	1/15	--	12
	1/16	TO	1/31	--	16
	2/1	TO	2/15	--	15
	2/16	TO	2/29	--	14
	3/1	TO	3/15	--	15
	3/16	TO	3/31	--	16
	4/1	TO	4/15	--	15
	4/16	TO	4/30	--	14
	5/1	TO	5/15	--	14
	5/16	TO	5/31	--	9
	6/1	TO	6/15	--	15
	6/16	TO	6/30	--	15

6. Models common monthly summary output file.

A common monthly summary of working days output file for the three modified models is presented in the next example. Year, month, and number of working days for each field operation for each month are presented in columns one to four, respectively

PRINT OUTPUT FILEC:\CAR\A.MON
 WEATHER DATA INPUTFILEC:\CAR\SI7792.IN
 DATE:06-21-1993 TIME:13:07:10
 INITIAL MOISTURE CONTENT .. 30 mm/150mm

SELECTIONS FOR THIS RUN ARE:

1. CROPVEGETABLES
 2. PERMANENT WILTING POINT 25.0 mm/150mm
 3. FIELD CAPACITY 45.0 mm/150mm
 4. INITIAL MOISTURE CONTENT 30.0 mm/150mm
 5. CRITERION FOR TILLAGE OPERATIONS 80 %
 6. CRITERION FOR NON-TILLAGE OPERATIONS .. 95 %

YEAR	MONTH	WORKING DAYS	
		TILLAGE	NON TILLAGE
1977	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	25
	6	30	--
	7	31	--
	8	21	--
	9	13	--
	10	--	28
	11	--	23
	12	--	31
1978	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	31
	6	24	--
	7	31	--
	8	17	--
	9	29	--
	10	--	20
	11	--	19
	12	--	31
1979	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	27
	6	9	--
	7	10	--
	8	23	--
	9	10	--
	10	--	24
	11	--	27
	12	--	31
1980	1	--	31
	2	--	29
	3	--	31
	4	--	30
	5	--	28
	6	24	--
	7	22	--
	8	31	--
	9	29	--
	10	--	26
	11	--	30
	12	--	31
1981	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	24
	6	18	--
	7	7	--
	8	28	--
	9	10	--
	10	--	21
	11	--	28
	12	--	24
1982	1	--	31
	2	--	28
	3	--	31

	4	--	30
	5	--	23
	6	30	--
	7	10	--
	8	29	--
	9	13	--
	10	--	29
	11	--	29
	12	--	31
1983			
	1	--	31
	2	--	28
	3	--	28
	4	--	24
	5	--	30
	6	21	--
	7	21	--
	8	17	--
	9	16	--
	10	--	28
	11	--	22
	12	--	31
1984			
	1	--	31
	2	--	29
	3	--	31
	4	--	30
	5	--	31
	6	26	--
	7	16	--
	8	25	--
	9	8	--
	10	--	25
	11	--	15
	12	--	31
1985			
	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	26
	6	30	--
	7	28	--
	8	26	--
	9	10	--
	10	--	15
	11	--	30
	12	--	31
1986			
	1	--	31
	2	--	28
	3	--	30
	4	--	30
	5	--	26
	6	23	--
	7	31	--
	8	31	--
	9	30	--
	10	--	27
	11	--	26
	12	--	31
1987			
	1	--	31
	2	--	28
	3	--	31
	4	--	30
	5	--	27
	6	8	--
	7	24	--
	8	30	--
	9	16	--
	10	--	23
	11	--	20
	12	--	25
1988			
	1	--	31
	2	--	29
	3	--	31
	4	--	30
	5	--	31
	6	19	--
	7	28	--
	8	20	--
	9	13	--
	10	--	30
	11	--	28
	12	--	31

APPENDIX B

APPENDIX B: Computer programs

The computer program listed in the first section is common for all the models except on the algorithm for the computation of soil moisture content and the selection of the soil coefficients. The most important variables are listed in the first section. Variables that differ in the second and the third computer program lists from the first one are included in each list.

1. Modified Hunt (1986) model.
2. Modified Tulu et al. (1974) model.
3. Modified Babeir et al. (1986) model.

1. Modified Hunt (1986) model.

'THIS SIMULATION PROGRAM CAN BE USED TO COMPUTE
'PROBABILITIES OF WORKING DAYS FOR FIELD OPERATIONS
'BASED ON SOIL MOISTURE CONTENT IN THE FIRST 150 mm LAYER
'AS A FUNCTION OF WEATHER DATA FOR THE SOUTH COAST OF PUERTO RICO.
'PWD MODEL DEVELOPED BY D. HUNT (1986) IS USED AS A REFERENCE ON THIS STUDY.
'THIS MODEL COMPUTES PWD FOR TILLAGE AND NON-TILLAGE OPERATIONS ON VEGETABLES
'OR SUGARCANE HARVESTING OPERATIONS."

WRITTEN BY CARLOS I. SEMIDEI
1993

'VARIABLES:

'FC = FIELD CAPACITY
'WP = PERMANENT WILTING POINT
'RNC = RUNOFF COEFFICIENT
'T = TILLAGE OPERATIONS WORKING DAY CRITERION
'TN = NON-TILLAGE OPERATIONS WORKING DAY CRITERION
'STMOIST = INITIAL MOISTURE CONTENT FOR THE DAY BEFORE TO START
' THE SMC COMPUTATIONS
'IMOIST = INITIAL MOISTURE CONTENT DURING THE SIMULATION PROCESS
'CROP = TYPE OF CROP USED TO COMPUTE THE PWD
'CROP = 1 FOR VEGETABLES
'CROP = 2 FOR SUGARCANE
'OPERMONTH1 TO OPERMONTH12 = ARE USED TO SELECT THE FIELD OPERATIONS TO
' BE SIMULATED FOR THE SPECIFIC MONTH (FROM JANUARY TO DECEMBER)
' (OPERMONTH_ SHOULD BE 1 OR 2)
' OPERMONTH1 = 1 MEANS THAT JANUARY WILL BE SIMULATED AS A TILLAGE OPERATION MONTH
' OPERMONTH5 = 2 MEANS THAT MAY WILL BE SIMULATED AS A NON-TILLAGE OPERATION MONTH
'OPERMONTH = WITHOUT NUMBERS (OPERMONTH) IS USED TO IDENTIFY THE PRINT OUTPUT
' OPTION FOR THE SPECIFIC MONTH
' OPERMONTH = 1 MEANS THAT THE REFERED MONTH IS A TILLAGE MONTH
' OPERMONTH = 2 MEANS THAT THE REFERED MONTH IS A NON-TILLAGE MONTH
'KC1 TO KC12 = ARE USED TO SPECIFY THE CROP COEFFICIENT FOR THE GROWING SEASON
' FOR ERACH MONTH
'OUTF = TYPE OF PRINTOUT FOR THE SIMULATION PROCESS.
' = 1 FOR DAILY OUTPUT. THIS CREATE OUTPUT FILE WITH EXTENTION ".DAY"
' = 2 FOR BYWEEKLY OUTPUT. THIS CREATE OUTPUT FILE WITH EXTENTION ".BMN"
' = 3 FOR MONTHLY OUTPUT. THIS CREATE OUTPUT FILE WITH EXTENTION ".MON"
'DRIVE\$ = DRIVE WHERE IS THE INPUT FILE AND WHERE THE OUTPUT FILES WILL BE CREATED
'RUN\$ = NAME OF THE CURRENT SIMULATION.
'WEATHER\$ = WEATHER DATA INPUT FILENAME. THIS IS CREATED WITH THE EXTENSION ".IN"
'YEAR = YEAR IN SIMULATION. THE YEAR IS IN THE INPUT FILE.
'MONTH = MONTH IN SIMULATION. THE MONTH IS IN THE INPUT FILE.
'N = DAY IN SIMULATION. THE DAY IS IN THE INPUT FILE.
'RAIN = RAINFALL FOR DAY N
'EP = PAN EVAPORATION FOR DAY N
'KP = EVAPORATION PAN COEFFICIENT
'PET = POTENTIAL EVAPOTRANSPIRATION FOR DAY N
'ET = EVAPOTRANSPIRATION FOR DAY N
'CHMOIST = CHANGE IN SOIL MOISTURE AFTER ET DURING DAY N
'MAXSAT = MAXIMUM SATURATION
'S = RETENTION PARAMETER OF SOIL MOISTURE RELATED WITH THE INITIAL INITIAL MOISTURE CONTENT
' DURING DAY N
'Q = SURFACE RUNOFF FOR DAY N
'WATERINF = INFILTRATION OF WATER AFTER RUNOFF
'DRAIN = DRAINAGE FROM THE SOIL DURING DAY N
'RCHMOIST = CHANGE IN SOIL MOISTURE AFTER DRAINAGE DURING DAY N
'MOIST = SOIL MOISURE CONTENT DURING DAY N
'WT = SOIL MOISTURE CONTENT WORKING DAY CRITERION FOR TILLAGE OPERATIONS
'WTN = SOIL MOISTURE CONTENT WORKING DAY CRITERION FOR NON-TILLAGE OPERATIONS
'WTV = WORKING OR NON WORKING DAY DEFINITION FOR TILLAGE OPERATIONS DURING DAY N
'WTV = 1 FOR WORKING DAY
'WTV = 2 FOR NON-WORKING DAY
'WTNV = WORKING OR NON WORKING DAY DEFINITION FOR NON-TILLAGE OPERATIONS DURING DAY N
'WTNV = 1 FOR WORKING DAY
'WTNV = 2 FOR NON-WORKING DAY
'PWDT = SUM OF TILLAGE WORKING DAYS PER MONTH USED AS INPUT COMPUTE THE PWD TABLE
'PBDTN = SUM OF NON-TILLAGE WORKING DAYS PER MONTH USED AS INPUT COMPUTE THE PWD TABLE
'TILL = SUM OF TILLAGE WORKING DAYS USED AS OUTPUT ON THE BYMONTHLY OR MONTHLY OUTPUT FILES
'PBDTN = SUM OF NON-TILLAGE WORKING DAYS PER MONTH USED AS INPUT COMPUTE THE PWD TABLE
'YEARCOUNT = IS USED TO COUNT THE NUMBER OF YEAR SIMULATED.

***** DECLARATION OF SUBROUTINE USED TO SORT NUMBER OF WORKING DAYS *****

DECLARE SUB SortSI2N (Num2Array%, RowCount%, SortCol%)

```

***** SELECT DRIVE WHERE THE INPUT DATA FILE IS LOCATED AND *****
***** THE OUTPUT FILES WILL BE SENT *****
CLS

PRINT "PRESS ANY KEY TO START"
WHILE INKEY$ = "": WEND
INPUT "ENTER DRIVE NAME: ", DRIVES$
PRINT "DRIVE SELECTED: "; DRIVES$
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND
CLS

***** DEFAULT VARIABLES *****

STMOIST = 30
FC = 45
WP = 25
RNC = 1
T = 90
TN = 95

***** SELECTION OF CROP *****

PRINT "SELECT CROP"
PRINT "1. VEGETABLES"
PRINT "2. SUGARCANE"
CROPSSEL:
INPUT "SELECTION (1 OR 2):", CROP
IF (CROP <= 0) OR (CROP > 2) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO CROPSSEL
END IF
IF CROP = 1 THEN CROP$ = "VEGETABLES"
IF CROP = 2 THEN CROP$ = "SUGARCANE"
CLS

***** SELECTION OF SOIL PARTAMETERS *****

PRINT "      PERMANENT WILTING POINT WATER CONTENT WAS ASSUMED"; WP; " mm/150 mm "
PRINT "      FIELD CAPACITY WATER CONTENT WAS ASSUMED"; FC; " mm /150 mm "
PRINT "      INITIAL MOISTURE CONTENT FOR THE DATE BEFORE START THE COMPUTATIONS"
PRINT "      IS ASSUMED NEAR PERMANENT WILTING POINT: "; STMOIST; " mm/150 mm "
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND
INPUT "DO YOU WANT TO CHANGE ANY VALUE? (Y/N) ", CH$
IF CH$ = "Y" GOTO SOILPARCHG
IF CH$ = "N" GOTO RNCOEFF
SOILPARCHG:
PRINT "WHICH VALUE DO YOU WANT TO CHANGE?"
PRINT "      1. PERMANENT WILTING POINT ( "; SPC(0); WP; SPC(0); "mm/150mm)"
PRINT "      2. FIELD CAPACITY ( "; SPC(0); FC; SPC(0); "mm/150mm)"
PRINT "      3. INITIAL MOISTURE CONTENT ( "; SPC(0); STMOIST; SPC(0); "mm/150mm)"
INPUT CH
IF CH = 1 GOTO WPCH
IF CH = 2 GOTO FCCH
IF CH = 3 GOTO IMCH
IF CH THEN ELSE
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1, 2, OR 3 "
    GOTO SOILPARCHG
WPCH:
PRINT "WILTING POINT IS ASSUMED "; SPC(0); WP; SPC(0); " mm/150mm. "
PRINT "ENTER NEW VALUE"
INPUT WP
GOTO SOILPARNEXT
FCCH:
PRINT "FIELD CAPACITY IS ASSUMED "; SPC(0); FC; SPC(0); " mm/150mm. "
PRINT "ENTER NEW VALUE"
INPUT FC
GOTO SOILPARNEXT
IMCH:
PRINT "INITIAL MOISTURE CONTENT IS ASSUMED "; SPC(0); STMOIST; SPC(0); "mm/150mm. "
PRINT "ENTER NEW VALUE"
INPUT STMOIST
IF STMOIST < WP THEN

```

```

BEEP
PRINT "INPUT ERROR DETECTED....."
PRINT "INITIAL MOISTURE CONTENT SHOULD BE GREATER THAN WP"
GOTO IMCH
END IF
GOTO SOILPARNEXT
SOILPARNEXT:
INPUT "DO YOU WANT TO CHANGE ANOTHER ONE? (Y/N)", ACH$
IF ACH$ = "Y" GOTO SOILPARCHG
IF ACH$ = "N" GOTO CHECKWPIM
CHECKWPIM:
IF STMOIST < WP THEN
CLS
BEEP
PRINT "INPUT ERROR DETECTED....."
PRINT "WILTING POINT SHOULD BE LESS THAN INITIAL MOISTURE CONTENT "
PRINT "FOR THIS RUN WILTING POINT = "; SPC(0); WP; SPC(0); "mm/150mm AND"
PRINT "INITIAL MOISTURE CONTENT = "; SPC(0); STMOIST; SPC(0); "mm/150mm"
PRINT "WHICH ONE DO YOU WANT TO CHANGE?"
PRINT "  1. WILTING POINT ("; SPC(0); WP; SPC(0); "mm/150mm)"
PRINT "  2. INITIAL MOISTURE CONTENT ("; SPC(0); STMOIST; SPC(0); "mm/150mm)"
PRINT "  3. BOTH"
INPUT OCH
IF OCH = 1 THEN
PRINT "ENTER NEW WILTING POINT VALUE "
INPUT WP
GOTO SOILCOEFF
END IF
IF OCH = 2 THEN
PRINT "ENTER NEW INITIAL MOISTURE VALUE"
INPUT STMOIST
GOTO SOILCOEFF
END IF
IF OCH = 3 THEN
PRINT "ENTER NEW WILTING POINT VALUE"
INPUT WP
PRINT "ENTER NEW INITIAL MOISTURE CONTENT"
INPUT STMOIST
GOTO SOILCOEFF
END IF
IF CH THEN ELSE
BEEP
PRINT "INPUT ERROR DETECTED....."
PRINT "SELECTION SHOULD BE 1, 2 OR 3"
PRINT "TRY AGAIN"
GOTO CHECKWPIM
END IF
SOILCOEFF:
IF STMOIST < WP THEN GOTO CHECKWPIM
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND
CLS
RNCOEFF:
PRINT " RUNOFF COEFFICIENT (RNC) IS USED TO ADJUST WATER RUNOFF."
PRINT " IT IS ASSUMED AS "; RNC
INPUT " DO YOU WANT TO CHANGE IT? (Y/N) ", RNC$
IF RNC$ = "Y" GOTO RNCCHN
IF RNC$ = "N" GOTO SOILMDEC
RNCCHN:
INPUT "ENTER NEW RUNOFF COEFFICIENT: ", RNC
SOILMDEC:

***** SELECTION OF FIELD OPERATION CRITERIA *****

CLS
PRINT "A DAY IS ASSUMED TO BE SUITABLE FOR TILLAGE OPERATIONS (PLOW, ETC)"
PRINT "WHEN THE SOIL MOISTURE CONTENT IS LESS THAN "; T; " % OF THE FIELD CAPACITY"
PRINT "A DAY IS ASSUMED TO BE SUITABLE FOR NON TILLAGE OPERATIONS (SPRAYING, ETC.)"
PRINT "WHEN THE SOIL MOISTURE CONTENT IS LESS THAN "; TN; " % OF THE FIELD CAPACITY"
INPUT "DO YOU WANT TO CHANGE ANY OF THESE PERCENTAGES? (Y/N)", K$
IF K$ = "Y" GOTO SOILMDECCH
IF K$ = "N" GOTO OPERPERMTH
SOILMDECCH:
PRINT "WHICH PERCENTAGE DO YOU WANT TO CHANGE?"
PRINT "      1. FOR TILLAGE OPERATIONS ("; SPC(0); T; SPC(0); "%)"
PRINT "      2. FOR NO TILLAGE OPERATIONS ("; SPC(0); TN; SPC(0); "%)"
INPUT K
IF K = 1 THEN GOTO TILLAGEDEC:

```

```

IF K = 2 THEN GOTO NONTILLAGEDEC:
IF K THEN ELSE
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2"
  PRINT "TRY AGAIN"
  GOTO SOILMDECCH
TILLAGEDEC:
INPUT "ENTER NEW PERCENT FOR TILLAGE OPERATIONS: ", T
GOTO CHECKSOILMDEC
NONTILLAGEDEC:
INPUT "ENTER NEW PERCENTAGE FOR NO TILLAGE OPERATIONS: ", TN
CHECKSOILMDEC:
INPUT "DO YOU WANT TO CHANGE ANOTHER ONE? (Y/N)", CH$
IF CH$ = "Y" THEN GOTO SOILMDECCH
IF CH$ = "N" THEN GOTO OPERPERMTH
OPERPERMTH:

/ ***** SELECTION OF FIELD OPERATION MONTHS AND CROP COEFFICIENTS *****
/ ***** FOR VEGETABLES *****

CLS
PRINT "FIELD OPERATIONS ARE ASSUMED TO BE PERFORMED"
PRINT "ACCORDING TO THE GROWING SEASON OF"; SPC(1); CROP$
IF CROP = 1 THEN GOTO OPERSELVEG
IF CROP = 2 THEN GOTO OPERSELSUG
OPERSELVEG:
PRINT "SELECT OPERATIONS TO BE PERFORMED ON EACH MONTH"
PRINT "1 FOR TILLAGE; 2 FOR NON-TILLAGE AND"
PRINT "ENTER CROP COEFFICIENT FOR THE MONTH."
OPERSELECTION1:
INPUT "1. JANUARY (1 OR 2)?", OPERMONTH1
IF (OPERMONT1 > 2) OR (OPERMONT1 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION1
END IF
KCSELECTION1:
INPUT "ENTER KC FOR JANUARY: ", KC1
IF KC1 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION1
END IF
OPERSELECTION2:
INPUT "2. FEBRUARY (1 OR 2)? ", OPERMONTH2
IF (OPERMONT2 > 2) OR (OPERMONT2 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION2
END IF
KCSELECTION2:
INPUT "ENTER KC FOR FEBRUARY: ", KC2
IF KC2 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION2
END IF
OPERSELECTION3:
INPUT "3. MARCH (1 OR 2)? ", OPERMONTH3
IF (OPERMONT3 > 2) OR (OPERMONT3 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION3
END IF
INPUT "ENTER KC FOR MARCH: ", KC3
KCSELECTION3:
IF KC3 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION3
END IF

```

```

OPERSELECTION4:
INPUT "4. APRIL (1 OR 2)? ", OPERMONTH4
IF (OPERMONTH4 > 2) OR (OPERMONTH4 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION4
END IF
KCSELECTION4:
INPUT "ENTER KC FOR APRIL: ", KC4
IF KC4 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION4
END IF
OPERSELECTION5:
INPUT "5. MAY (1 OR 2)? ", OPERMONTH5
IF (OPERMONTH5 > 2) OR (OPERMONTH5 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION5
END IF
KCSELECTION5:
INPUT "ENTER KC FOR MAY: ", KC5
IF KC5 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION5
END IF
OPERSELECTION6:
INPUT "6. JUNE (1 OR 2)? ", OPERMONTH6
IF (OPERMONTH6 > 2) OR (OPERMONTH6 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION6
END IF
KCSELECTION6:
INPUT "ENTER KC FOR JUNE: ", KC6
IF KC6 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION6
END IF
OPERSELECTION7:
INPUT "7. JULY (1 OR 2)? ", OPERMONTH7
IF (OPERMONTH7 > 2) OR (OPERMONTH7 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION7
END IF
KCSELECTION7:
INPUT "ENTER KC FOR JULY: ", KC7
IF KC7 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION7
END IF
OPERSELECTION8:
INPUT "8. AUGUST (1 OR 2)? ", OPERMONTH8
IF (OPERMONTH8 > 2) OR (OPERMONTH8 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION8
END IF
KCSELECTION8:
INPUT "ENTER KC FOR AUGUST: ", KC8
IF KC8 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"

```

```

        GOTO KCSELECTION8
    END IF
OPERSELECTION9:
INPUT "9. SEPTEMBER (1 OR 2)? ", OPERMONTH9
IF (OPERMONTH9 > 2) OR (OPERMONTH9 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION9
END IF
KCSELECTION9:
INPUT "ENTER KC FOR SEPTEMBER :", KC9
IF KC9 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION9
END IF
OPERSELECTION10:
INPUT "10. OCTOBER (1 OR 2)? ", OPERMONTH10
IF (OPERMONTH10 > 2) OR (OPERMONTH10 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION10
END IF
KCSELECTION10:
INPUT "ENTER KC FOR OCTOBER: ", KC10
IF KC10 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION10
END IF
OPERSELECTION11:
INPUT "11. NOVEMBER (1 OR 2)? ", OPERMONTH11
IF (OPERMONTH11 > 2) OR (OPERMONTH11 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO KCSELECTION11
END IF
KCSELECTION11:
INPUT "ENTER KC FOR NOVEMBER: ", KC11
IF KC11 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION11
END IF
OPERSELECTION12:
INPUT "12. DECEMBER (1 OR 2)? ", OPERMONTH12
IF (OPERMONTH12 > 2) OR (OPERMONTH12 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION12
END IF
KCSELECTION12:
INPUT "ENTER KC FOR DECEMBER: ", KC12
IF KC12 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION12
END IF
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND
GOTO COMPUTATION

/ ***** SELECTION OF FIELD OPERATION MONTHS AND CROP COEFFICIENTS *****
/ ***** FOR SUGARCANE *****

OPERSELSUG:
PRINT "SELECT MONTHS FOR SUGARCANE HARVESTING OPERATIONS"
PRINT "1 FOR HARVESTING OPERATION MONTH ; 2 FOR NON HARVESTING OPERATION MONTH."
PRINT "AT THE SAME TIME ENTER CROP COEFFICIENT FOR THE MONTH."
OPERSELECTION21:

```

```

INPUT "1. JANUARY (1 OR 2)?", OPERMONTH1
IF (OPERMONT1 > 2) OR (OPERMONT1 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION21
END IF
KCSELECTION21:
INPUT "ENTER KC FOR JANUARY: ", KC1
IF KC1 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION21
END IF
OPERSELECTION22:
INPUT "2. FEBRUARY (1 OR 2)? ", OPERMONTH2
IF (OPERMONT2 > 2) OR (OPERMONT2 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION22
END IF
KCSELECTION22:
INPUT "ENTER KC FOR FEBRUARY: ", KC2
IF KC2 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION22
END IF
OPERSELECTION23:
INPUT "3. MARCH (1 OR 2)? ", OPERMONTH3
IF (OPERMONT3 > 2) OR (OPERMONT3 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION23
END IF
INPUT "ENTER KC FOR MARCH: ", KC3
KCSELECTION23:
IF KC3 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION23
END IF
OPERSELECTION24:
INPUT "4. APRIL (1 OR 2)? ", OPERMONTH4
IF (OPERMONT4 > 2) OR (OPERMONT4 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION24
END IF
KCSELECTION24:
INPUT "ENTER KC FOR APRIL: ", KC4
IF KC4 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION24
END IF
OPERSELECTION25:
INPUT "5. MAY (1 OR 2)? ", OPERMONTH5
IF (OPERMONT5 > 2) OR (OPERMONT5 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION25
END IF
KCSELECTION25:
INPUT "ENTER KC FOR MAY: ", KC5
IF KC5 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION25

```

```

      END IF
OPERSELECTION26:
INPUT "6. JUNE (1 OR 2)? ", OPERMONTH6
IF (OPERMONTH6 > 2) OR (OPERMONTH6 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION26
END IF
KCSELECTION26:
INPUT "ENTER KC FOR JUNE: ", KC6
IF KC6 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION26
END IF
OPERSELECTION27:
INPUT "7. JULY (1 OR 2)? ", OPERMONTH7
IF (OPERMONTH7 > 2) OR (OPERMONTH7 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION27
END IF
KCSELECTION27:
INPUT "ENTER KC FOR JULY: ", KC7
IF KC7 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION27
END IF
OPERSELECTION28:
INPUT "8. AUGUST (1 OR 2)? ", OPERMONTH8
IF (OPERMONTH8 > 2) OR (OPERMONTH8 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION28
END IF
KCSELECTION28:
INPUT "ENTER KC FOR AUGUST: ", KC8
IF KC8 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION28
END IF
OPERSELECTION29:
INPUT "9. SEPTEMBER (1 OR 2)? ", OPERMONTH9
IF (OPERMONTH9 > 2) OR (OPERMONTH9 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION29
END IF
KCSELECTION29:
INPUT "ENTER KC FOR SEPTEMBER: ", KC9
IF KC9 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "KC MUST BE GREATER THAN 0.35"
  GOTO KCSELECTION29
END IF
OPERSELECTION210:
INPUT "10. OCTOBER (1 OR 2)? ", OPERMONTH10
IF (OPERMONTH10 > 2) OR (OPERMONTH10 = 0) THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 OR 2."
  GOTO OPERSELECTION210
END IF
KCSELECTION210:
INPUT "ENTER KC FOR OCTOBER: ", KC10
IF KC10 < .35 THEN
  BEEP
  PRINT "INPUT ERROR DETECTED....."

```



```

        PRINT "KC MUST BE GREATER THAN 0.35"
        GOTO KCSELECTION210
    END IF
OPERSELECTION211:
INPUT "11. NOVEMBER (1 OR 2)? ", OPERMONTH11
IF (OPERMONT11 > 2) OR (OPERMONT11 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO KCSELECTION211
END IF
KCSELECTION211:
INPUT "ENTER KC FOR NOVEMBER: ", KC11
IF KC11 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION211
END IF
OPERSELECTION212:
INPUT "12. DECEMBER (1 OR 2)? ", OPERMONTH12
IF (OPERMONT11 > 2) OR (OPERMONT11 = 0) THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "SELECTION SHOULD BE 1 OR 2."
    GOTO OPERSELECTION212
END IF
KCSELECTION212:
INPUT "ENTER KC FOR DECEMBER: ", KC12
IF KC12 < .35 THEN
    BEEP
    PRINT "INPUT ERROR DETECTED....."
    PRINT "KC MUST BE GREATER THAN 0.35"
    GOTO KCSELECTION212
END IF
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND
COMPUTATION:
IMOIST = STMOIST / STMOIST IS CONVERTED TO IMOIST FOR DAY N-1
CLS

/***** ENDS SELECTION OF FOR THE RUN *****/

/***** SHOWS SELECTIONS FOR THE SIMULATION *****/

PRINT "SELECTIONS FOR THIS RUN ARE:"
PRINT "  1. CROP ..... "; SPC(0); CROP$
PRINT "  2. PERMANENT WILTING POINT ..... "; : PRINT USING "###."; SPC(0); WP;
    SPC(0); : PRINT " mm/150mm"
PRINT "  3. FIELD CAPACITY ..... "; : PRINT USING "###."; SPC(0); FC;
    SPC(0); : PRINT " mm/150mm"
PRINT "  4. INITIAL MOISTURE CONTENT ..... "; : PRINT USING "###."; SPC(0);
    STMOIST; SPC(0); : PRINT " mm/150mm"
PRINT "  5. RUNOFF COEFFICIENT ..... "; RNC
PRINT "  6. CRITERION FOR TILLAGE OPERATIONS ....."; SPC(0); T; SPC(0); "%"
PRINT "  7. CRITERION FOR NON-TILLAGE OPERATIONS .."; SPC(0); TN; SPC(0); "%"
PRINT
INPUT "TYPE NAME OF OUTPUT FILE FOR THIS RUN: ", RUN$

/***** SELECTION OF THE TYPE OF OUTPUT FILE *****/

PRINT
INPUT "TYPE WEATHER DATA INPUT FILE NAME:", WEATHER$
PRINT "HOW DO YOU WANT THE OUTPUT FILE?"
PRINT "  1. DAILY SUMMARIES"
PRINT "  2. BIMONTHLY SUMMARIES"
PRINT "  3. MONTHLY SUMMARIES"
INPUT ; OUTF
CLS
PRINT "NOW I'M SIMULATING ..... PLEASE WAIT"
OPEN DRIVE$ + WEATHER$ + ".IN" FOR INPUT AS #4
    INPUT #4, YEAR
    INPUT #4, MONTH, N
    PRINT "SIMULATING NOW YEAR:"
    PRINT YEAR
OPEN DRIVE$ + RUN$ + ".pwd" FOR OUTPUT AS #6
IF OUTF = 1 THEN
    OPEN DRIVE$ + RUN$ + ".DAY" FOR OUTPUT AS #1

```

```

PRINT #1, "PRINT OUTPUT FILE ....."; DRIVES$; SPC(0); RUN$; SPC(0); ".DAY BASED ON
HUNT MODEL"
PRINT #1, "WEATHER DATA INPUTFILE ...."; DRIVES$; SPC(0); WEATHER$; SPC(0); ".IN"
PRINT #1, "DATE:"; SPC(0); DATES$; SPC(5); "TIME:"; SPC(0); TIME$
PRINT #1, "SELECTIONS FOR THIS RUN ARE:"
PRINT #1, "      1. CROP ....."; SPC(0); CROP$
PRINT #1, "      2. PERMANENT WILTING POINT ..... "; : PRINT #1, USING "###.#";
      SPC(0); WP; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      3. FIELD CAPACITY ..... "; : PRINT #1, USING "###.#";
      SPC(0); FC; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      4. INITIAL MOISTURE CONTENT ..... "; : PRINT #1, USING "###.#";
      SPC(0); STMOIST; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      5. RUNOFF COEFFICIENT ..... "; RNC
PRINT #1, "      6. CRITERION FOR TILLAGE OPERATIONS ..... "; SPC(0); T; SPC(0); "%"
PRINT #1, "      7. CRITERION FOR NON-TILLAGE OPERATIONS .. "; SPC(0); TN; SPC(0); "%"
      P      R      I      N      T      #      1
"-----"
PRINT #1, "YEAR MONTH DAY | PET  ET   RAIN  R-OFF DRAIN  MOIST |   OPERATION"
PRINT #1, "-----"
PRINT #1, "      | ----- mm/day ----- | TILLAGE | NON "
PRINT #1, "      | ----- | TILLAGE"
"-----"
PRINT #1, YEAR
END IF
IF OUTF = 2 THEN
OPEN DRIVES$ + RUN$ + ".BMN" FOR OUTPUT AS #2
PRINT #2, "PRINT OUTPUT FILE ....."; DRIVES$; SPC(0); RUN$; SPC(0); ".BMN BASED ON
HUNT MODEL"
PRINT #2, "WEATHER DATA INPUTFILE .... "; DRIVES$; SPC(0); WEATHER$; SPC(0); ".IN"
PRINT #2, "DATE:"; SPC(0); DATES$; SPC(5); "TIME:"; SPC(0); TIME$
PRINT #2, "SELECTIONS FOR THIS RUN ARE:"
PRINT #2, "      1. CROP ....."; SPC(0); CROP$
PRINT #2, "      2. PERMANENT WILTING POINT ..... "; : PRINT #2, USING "###.#";
      SPC(0); WP; SPC(0); : PRINT #2, " mm/150mm"
PRINT #2, "      3. FIELD CAPACITY ..... "; : PRINT #2, USING "###.#";
      SPC(0); FC; SPC(0); : PRINT #2, " mm/150mm"
PRINT #2, "      4. INITIAL MOISTURE CONTENT ..... "; : PRINT #2, USING "###.#";
      SPC(0); STMOIST; SPC(0); : PRINT #2, " mm/150mm"
PRINT #2, "      5. RUNOFF COEFFICIENT ..... "; RNC
PRINT #2, "      6. CRITERION FOR TILLAGE OPERATIONS ..... "; SPC(0); T; SPC(0); "%"
PRINT #2, "      7. CRITERION FOR NON-TILLAGE OPERATIONS .. "; SPC(0); TN; SPC(0); "%"
PRINT #2, "-----"
PRINT #2, "      YEAR      |      PERIOD      | ----- WORKING DAYS -----"
PRINT #2, "      |      |      | TILLAGE | NON TILLAGE "
PRINT #2, "-----"
PRINT #2, SPC(2); YEAR
END IF
IF OUTF = 3 THEN
OPEN DRIVES$ + RUN$ + ".MON" FOR OUTPUT AS #3
PRINT #3, "PRINT OUTPUT FILE ....."; DRIVES$; SPC(0); RUN$; SPC(0); ".MON"
PRINT #3, "WEATHER DATA INPUTFILE ...."; DRIVES$; SPC(0); WEATHER$; SPC(0); ".IN"
PRINT #3, "DATE:"; SPC(0); DATES$; SPC(5); "TIME:"; SPC(0); TIME$
PRINT #3, "INITIAL MOISTURE CONTENT .. "; SPC(0); STMOIST; SPC(1); "mm/150mm"
PRINT #3, "SELECTIONS FOR THIS RUN ARE:"
PRINT #3, "      1. CROP ....."; SPC(0); CROP$
PRINT #3, "      2. PERMANENT WILTING POINT ..... "; : PRINT #3, USING "###.#";
      SPC(0); WP; SPC(0); : PRINT #3, " mm/150mm"
PRINT #3, "      3. FIELD CAPACITY ..... "; : PRINT #3, USING "###.#";
      SPC(0); FC; SPC(0); : PRINT #3, " mm/150mm"
PRINT #3, "      4. INITIAL MOISTURE CONTENT ..... "; : PRINT #3, USING "###.#";
      SPC(0); STMOIST; SPC(0); : PRINT #3, " mm/150mm"
PRINT #3, "      5. RUNOFF COEFFICIENT ..... "; RNC
PRINT #3, "      6. CRITERION FOR TILLAGE OPERATIONS ..... "; SPC(0); T; SPC(0); "%"
PRINT #3, "      7. CRITERION FOR NON-TILLAGE OPERATIONS .. "; SPC(0); TN; SPC(0); "%"
PRINT #3, "-----"
PRINT #3, "      YEAR      | MONTH      |      WORKING DAYS      "
PRINT #3, "      |      |      | -----"
PRINT #3, "      |      |      | TILLAGE | NON TILLAGE "
PRINT #3, "-----"
PRINT #3, SPC(1); YEAR
END IF

```

***** STARTS COMPUTATIONS OF SOIL MOISTURE CONTENT *****

```

DO UNTIL EOF(4)
  INPUT #4, MONTH, N, RAIN, EP
  EVAPOTRANSPIRATION:
    EP = (EP * 25.4 / 100) ' CONVERTS EP FROM HUNDREDTHS INCHES TO MILLIMETERS
    KP = 0.8
    PET = EP * KP
    IF MONTH = 1 THEN ET = PET * KC1
    IF MONTH = 2 THEN ET = PET * KC2
    IF MONTH = 3 THEN ET = PET * KC3
    IF MONTH = 4 THEN ET = PET * KC4
    IF MONTH = 5 THEN ET = PET * KC5
    IF MONTH = 6 THEN ET = PET * KC6
    IF MONTH = 7 THEN ET = PET * KC7
    IF MONTH = 8 THEN ET = PET * KC8
    IF MONTH = 9 THEN ET = PET * KC9
    IF MONTH = 10 THEN ET = PET * KC10
    IF MONTH = 11 THEN ET = PET * KC11
    IF MONTH = 12 THEN ET = PET * KC12
  IF CROP = 2 THEN
    IF MONTH = 1 THEN ET = PET * KC1 * .6
    IF MONTH = 2 THEN ET = PET * KC2 * .6
    IF MONTH = 3 THEN ET = PET * KC3 * .6
    IF MONTH = 4 THEN ET = PET * KC4 * .6
    IF MONTH = 5 THEN ET = PET * KC5 * .6
    IF MONTH = 6 THEN ET = PET * KC6 * .6
    IF MONTH = 7 THEN ET = PET * KC7 * .6
    IF MONTH = 8 THEN ET = PET * KC8 * .6
    IF MONTH = 9 THEN ET = PET * KC9 * .6
    IF MONTH = 10 THEN ET = PET * KC10 * .6
    IF MONTH = 11 THEN ET = PET * KC11 * .6
    IF MONTH = 12 THEN ET = PET * KC12 * .6
  END IF
  IF IMOIST = WP THEN
    ET = 0
    GOTO ETEND
  END IF
  IF IMOIST - ET < WP THEN
    ET = IMOIST - WP
  END IF
ETEND:
  CHMOIST = IMOIST - ET
RUNOFF:
  RAIN = RAIN * 25.4 ' CONVERTS RAIN FROM INCHES TO MILLIMETERS
  MAXSAT = FC * 1.15
  S = (MAXSAT - CHMOIST) * RNC
  IF RAIN = 0 THEN
    Q = 0
    GOTO RUNOFFEND
  END IF
  IF RAIN < (.2 * S) THEN
    Q = 0
    GOTO RUNOFFEND
  END IF
  IF RAIN > (.2 * S) THEN
    Q = (RAIN - (.2 * S)) ^ 2 / (RAIN + (.8 * S))
  END IF
RUNOFFEND:
  WATERINF = RAIN - Q
  RCHMOIST = CHMOIST + WATERINF
DRAINAGE:
  IF RCHMOIST < FC THEN
    DRAIN = 0
    GOTO DRAINAGEEND
  END IF
  IF RCHMOIST > FC THEN
    IF RCHMOIST < MAXSAT THEN
      DRAIN = (RCHMOIST - FC) / 2
      GOTO DRAINAGEEND
    END IF
  END IF
  IF RCHMOIST > MAXSAT THEN
    DRAIN = (MAXSAT - FC) / 3
  END IF
DRAINAGEEND:
  MOIST = RCHMOIST - DRAIN

```

***** DEFINES THE FIELD OPERATIONS BY MONTH AND CROP *****

```

IF OPERMONTH1 = 1 THEN
  IF MONTH = 1 THEN OPERMONTH = 1
END IF
IF OPERMONTH1 = 2 THEN
  IF MONTH = 1 THEN OPERMONTH = 2
END IF
IF OPERMONTH2 = 1 THEN
  IF MONTH = 2 THEN OPERMONTH = 1
END IF
IF OPERMONTH2 = 2 THEN
  IF MONTH = 2 THEN OPERMONTH = 2
END IF
IF OPERMONTH3 = 1 THEN
  IF MONTH = 3 THEN OPERMONTH = 1
END IF
IF OPERMONTH3 = 2 THEN
  IF MONTH = 3 THEN OPERMONTH = 2
END IF
IF OPERMONTH4 = 1 THEN
  IF MONTH = 4 THEN OPERMONTH = 1
END IF
IF OPERMONTH4 = 2 THEN
  IF MONTH = 4 THEN OPERMONTH = 2
END IF
IF OPERMONTH5 = 1 THEN
  IF MONTH = 5 THEN OPERMONTH = 1
END IF
IF OPERMONTH5 = 2 THEN
  IF MONTH = 5 THEN OPERMONTH = 2
END IF
IF OPERMONTH6 = 1 THEN
  IF MONTH = 6 THEN OPERMONTH = 1
END IF
IF OPERMONTH6 = 2 THEN
  IF MONTH = 6 THEN OPERMONTH = 2
END IF
IF OPERMONTH7 = 1 THEN
  IF MONTH = 7 THEN OPERMONTH = 1
END IF
IF OPERMONTH7 = 2 THEN
  IF MONTH = 7 THEN OPERMONTH = 2
END IF
IF OPERMONTH8 = 1 THEN
  IF MONTH = 8 THEN OPERMONTH = 1
END IF
IF OPERMONTH8 = 2 THEN
  IF MONTH = 8 THEN OPERMONTH = 2
END IF
IF OPERMONTH9 = 1 THEN
  IF MONTH = 9 THEN OPERMONTH = 1
END IF
IF OPERMONTH9 = 2 THEN
  IF MONTH = 9 THEN OPERMONTH = 2
END IF
IF OPERMONTH10 = 1 THEN
  IF MONTH = 10 THEN OPERMONTH = 1
END IF
IF OPERMONTH10 = 2 THEN
  IF MONTH = 10 THEN OPERMONTH = 2
END IF

IF OPERMONTH11 = 1 THEN
  IF MONTH = 11 THEN OPERMONTH = 1
END IF
IF OPERMONTH11 = 2 THEN
  IF MONTH = 11 THEN OPERMONTH = 2
END IF
IF OPERMONTH12 = 1 THEN
  IF MONTH = 12 THEN OPERMONTH = 1
END IF
IF OPERMONTH12 = 2 THEN
  IF MONTH = 12 THEN OPERMONTH = 2
END IF
IF MONTH = 12 THEN
  IF N = 31 THEN
    YEARCOUNT = YEARCOUNT + 1
  
```

END IF
END IF

***** STARTS TO DEFINE IF THE DAY N IS OR NOT A WORKING DAY *****

```
WT = (FC * T) / 100
WTN = (FC * TN) / 100
IF MOIST > WT THEN WTV = 0
IF MOIST < WT THEN WTV = 1
IF MOIST > WTN THEN WTNV = 0
IF MOIST < WTN THEN WTNV = 1
IMOIST = MOIST' MOIST FOR DAY N IS CONVERTED TO INITIAL MOISTURE FOR DAY N-1
PWDT = PWDT + WTV
PWDNT = PWDNT + WTNV
TILL = TILL + WTV
NTILL = NTILL + WTNV
```

***** STARTS PRINT OUTPUT FOR DAILY OPTION *****

```
IF OUTF = 1 THEN
  IF CROP = 1 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(7); MONTH; SPC(2); N; SPC(2); : PRINT #1, USING "###.#";
      PET; SPC(3); ET; SPC(3); RAIN; SPC(2); Q; SPC(2); DRAIN; SPC(3); MOIST; SPC(5); :
      PRINT #1, WTV; SPC(7); "-"
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(7); MONTH; SPC(2); N; SPC(2); : PRINT #1, USING
      "###.#"; PET; SPC(3); ET; SPC(3); RAIN; SPC(2); Q; SPC(2); DRAIN; SPC(3);
      MOIST; SPC(6); : PRINT #1, "-"; SPC(7); WTNV
    END IF
  END IF
  IF CROP = 2 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(7); MONTH; SPC(2); N; SPC(2); : PRINT #1, USING "###.#";
      PET; SPC(3); ET; SPC(3); RAIN; SPC(2); Q; SPC(2); DRAIN; SPC(3); MOIST; SPC(6); :
      PRINT #1, "-"; SPC(6); WTNV
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(7); MONTH; SPC(2); N; SPC(2); : PRINT #1, USING "###.#";
      PET; SPC(3); ET; SPC(3); RAIN; SPC(2); Q; SPC(2); DRAIN; SPC(3); MOIST; SPC(6); :
      PRINT #1, "-"; SPC(7); "-"
    END IF
  END IF
  IF (MONTH = 1) OR (MONTH = 3) OR (MONTH = 5) OR (MONTH = 7) OR (MONTH = 8) OR
  (MONTH = 10) OR (MONTH = 12) THEN
    IF N = 31 THEN
      PRINT #1,
    END IF
  END IF
  IF (MONTH = 4) OR (MONTH = 6) OR (MONTH = 9) OR (MONTH = 11) THEN
    IF N = 30 THEN
      PRINT #1,
    END IF
  END IF
  IF MONTH = 2 THEN
    IF (YEAR = 1980) OR (YEAR = 1984) OR (YEAR = 1988) OR (YEAR = 1992) THEN
      IF N = 29 THEN
        PRINT #1,
      END IF
    ELSE
      IF N = 28 THEN
        PRINT #1,
      END IF
    END IF
  END IF
  IF MONTH = 12 THEN
    IF N = 31 THEN
      INPUT #4, YEAR
      IF YEAR > 0 THEN
        PRINT #1, SPC(0); YEAR
        PRINT SPC(0); YEAR
      END IF
    END IF
  END IF
END IF
```

```

/ ***** STARTS PRINT OUTPUT FOR BIMONTHLY OPTION *****
IF OUTF = 2 THEN
  IF N = 15 THEN
    IF CROP = 1 THEN
      IF OPERMONTH = 1 THEN
        PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/1 TO ";
        : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
        : PRINT #2, USING "##"; N; SPC(13); TILL; SPC(15); : PRINT #2, "--"
        TILL = 0
        NTILL = 0
      END IF
      IF OPERMONTH = 2 THEN
        PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/1 TO ";
        : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
        : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(14); NTILL
        TILL = 0
        NTILL = 0
      END IF
    END IF
    IF CROP = 2 THEN
      IF OPERMONTH = 1 THEN
        PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/1 TO ";
        : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
        : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(13); NTILL
        TILL = 0
        NTILL = 0
      END IF
      IF OPERMONTH = 2 THEN
        PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/1 TO ";
        : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
        : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(14); "--"
        TILL = 0
        NTILL = 0
      END IF
    END IF
  END IF
  IF (MONTH = 1) OR (MONTH = 3) OR (MONTH = 5) OR (MONTH = 7) OR (MONTH = 8) OR
    (MONTH = 10) OR (MONTH = 12) THEN
    IF N = 31 THEN
      IF CROP = 1 THEN
        IF OPERMONTH = 1 THEN
          PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "##"; N; SPC(13); TILL; SPC(15); : PRINT #2, "--"
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(14); NTILL
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
      END IF
      IF CROP = 2 THEN
        IF OPERMONTH = 1 THEN
          PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(13); NTILL
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #2, USING "##"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "##"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "##"; N; SPC(13); : PRINT #2, "--"; SPC(14); "--"
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
      END IF
    END IF
  END IF
  IF (MONTH = 4) OR (MONTH = 6) OR (MONTH = 9) OR (MONTH = 11) THEN
    IF N = 30 THEN

```

```

IF CROP = 1 THEN
  IF OPERMONTH = 1 THEN
    PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
    : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
    : PRINT #2, USING "###"; N; SPC(13); TILL; SPC(15); : PRINT #2, "--"
    PRINT #2,
    TILL = 0
    NTILL = 0
  END IF
  IF OPERMONTH = 2 THEN
    PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
    : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
    : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(14); NTILL
    PRINT #2,
    TILL = 0
    NTILL = 0
  END IF
END IF
IF CROP = 2 THEN
  IF OPERMONTH = 1 THEN
    PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
    : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
    : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(13); NTILL
    PRINT #2,
    TILL = 0
    NTILL = 0
  END IF
  IF OPERMONTH = 2 THEN
    PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
    : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
    : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(14); "--"
    PRINT #2,
    TILL = 0
    NTILL = 0
  END IF
END IF
END IF
IF MONTH = 2 THEN
  IF (YEAR = 1980) OR (YEAR = 1984) OR (YEAR = 1988) OR (YEAR = 1992) THEN
    IF N = 29 THEN
      IF CROP = 1 THEN
        IF OPERMONTH = 1 THEN
          PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); TILL; SPC(15); : PRINT #2, "--"
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(14); NTILL
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
      END IF
      IF CROP = 2 THEN
        IF OPERMONTH = 1 THEN
          PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(13); NTILL
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(14); "--"
          PRINT #2,
          TILL = 0
          NTILL = 0
        END IF
      END IF
    END IF
  END IF
END IF

```

```

ELSE
  IF N = 28 THEN
    IF CROP = 1 THEN
      IF OPERMONTH = 1 THEN
        PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); TILL; SPC(15); : PRINT #2, "--"
        PRINT #2,
          TILL = 0
          NTILL = 0
      END IF
      IF OPERMONTH = 2 THEN
        PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(15); NTILL
        PRINT #2,
          TILL = 0
          NTILL = 0
      END IF
    END IF
    IF CROP = 2 THEN
      IF OPERMONTH = 1 THEN
        PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(13); NTILL
        PRINT #2,
          TILL = 0
          NTILL = 0
      END IF
      IF OPERMONTH = 2 THEN
        PRINT #2, USING "###"; SPC(15); MONTH; SPC(0); : PRINT #2, "/16 TO ";
          : PRINT #2, USING "###"; SPC(0); MONTH; SPC(0); : PRINT #2, "/"; SPC(0);
          : PRINT #2, USING "###"; N; SPC(13); : PRINT #2, "--"; SPC(15); "--"
        PRINT #2,
          TILL = 0
          NTILL = 0
      END IF
    END IF
  END IF
  IF MONTH = 12 THEN
    IF N = 31 THEN
      INPUT #4, YEAR
      IF YEAR > 0 THEN
        PRINT #2, SPC(1); YEAR
        PRINT YEAR
      END IF
    END IF
  END IF
END IF

```

***** START PRINT OUTPUT FOR MONTHLY OPTION *****

```

IF OUTF = 3 THEN
  IF (MONTH = 1) OR (MONTH = 3) OR (MONTH = 5) OR (MONTH = 7) OR (MONTH = 8) OR
    (MONTH = 10) OR (MONTH = 12) THEN
    IF N = 31 THEN
      IF CROP = 1 THEN
        IF OPERMONTH = 1 THEN
          PRINT #3, USING "###"; SPC(9); MONTH; SPC(7); TILL; SPC(10); : PRINT #3, "--"
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); NTILL
          TILL = 0
          NTILL = 0
        END IF
      END IF
      IF CROP = 2 THEN
        IF OPERMONTH = 1 THEN
          PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(8); NTILL
          TILL = 0
          NTILL = 0
        END IF
        IF OPERMONTH = 2 THEN
          PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); "--"
        END IF
      END IF
    END IF
  END IF

```



```

        TILL = 0
        NTILL = 0
    END IF
END IF
END IF
END IF
IF (MONTH = 4) OR (MONTH = 6) OR (MONTH = 9) OR (MONTH = 11) THEN
    IF N = 30 THEN
        IF CROP = 1 THEN
            IF OPERMONTH = 1 THEN
                PRINT #3, USING "###"; SPC(9); MONTH; SPC(7); TILL; SPC(10); : PRINT #3, "--"
                TILL = 0
                NTILL = 0
            END IF
            IF OPERMONTH = 2 THEN
                PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); NTILL
                TILL = 0
                NTILL = 0
            END IF
        END IF
        IF CROP = 2 THEN
            IF OPERMONTH = 1 THEN
                PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(8); NTILL
                TILL = 0
                NTILL = 0
            END IF
            IF OPERMONTH = 2 THEN
                PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); "--"
                TILL = 0
                NTILL = 0
            END IF
        END IF
    END IF
END IF
IF MONTH = 2 THEN
    IF (YEAR = 1980) OR (YEAR = 1984) OR (YEAR = 1988) OR (YEAR = 1992) THEN
        IF N = 29 THEN
            IF CROP = 1 THEN
                IF OPERMONTH = 1 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(7); TILL; SPC(10); : PRINT #3, "--"
                    TILL = 0
                    NTILL = 0
                END IF
                IF OPERMONTH = 2 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); NTILL
                    TILL = 0
                    NTILL = 0
                END IF
            END IF
            IF CROP = 2 THEN
                IF OPERMONTH = 1 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(8); NTILL
                    TILL = 0
                    NTILL = 0
                END IF
                IF OPERMONTH = 2 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); "--"
                    TILL = 0
                    NTILL = 0
                END IF
            END IF
        END IF
    ELSE
        IF N = 28 THEN
            IF CROP = 1 THEN
                IF OPERMONTH = 1 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(7); TILL; SPC(10); : PRINT #3, "--"
                    TILL = 0
                    NTILL = 0
                END IF
                IF OPERMONTH = 2 THEN
                    PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); NTILL
                    TILL = 0
                    NTILL = 0
                END IF
            END IF
            IF CROP = 2 THEN
                IF OPERMONTH = 1 THEN

```

```

        PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(8); NTILL
        TILL = 0
        NTILL = 0
    END IF
    IF OPERMONTH = 2 THEN
        PRINT #3, USING "###"; SPC(9); MONTH; SPC(8); : PRINT #3, "--"; SPC(9); "--"
        TILL = 0
        NTILL = 0
    END IF
END IF
END IF
END IF
END IF
IF MONTH = 12 THEN
    IF N = 31 THEN
        INPUT #4, YEAR
        IF YEAR > 0 THEN
            PRINT #3, SPC(1); YEAR
            PRINT YEAR
        END IF
    END IF
END IF
END IF
END IF

/***** STARTS PRINT OUTPUT TEMPORARY FILE *****/
/***** TO BE USED AS INPUT FILE IN THE COMPUTATION OF PWD *****/

    IF MONTH = 1 THEN
        IF N = 1 THEN
            PRINT #6, SPC(1); YEAR
        END IF
    END IF
10) IF (MONTH = 1) OR (MONTH = 3) OR (MONTH = 5) OR (MONTH = 7) OR (MONTH = 8) OR (MONTH =
    OR (MONTH = 12) THEN
        IF N = 31 THEN
            PRINT #6, USING "###"; SPC(2); MONTH; SPC(2); N; SPC(2); PWD; SPC(2); PWDNT
            PWD = 0
            PWDNT = 0
        END IF
    END IF
    IF (MONTH = 4) OR (MONTH = 6) OR (MONTH = 9) OR (MONTH = 11) THEN
        IF N = 30 THEN
            PRINT #6, USING "###"; SPC(2); MONTH; SPC(2); N; SPC(2); PWD; SPC(2); PWDNT
            PWD = 0
            PWDNT = 0
        END IF
    END IF
    IF MONTH = 2 THEN
        IF (YEAR = 1980) OR (YEAR = 1984) OR (YEAR = 1988) OR (YEAR = 1992) THEN
            IF N = 29 THEN
                PRINT #6, USING "###"; SPC(2); MONTH; SPC(2); N; SPC(2); PWD; SPC(2); PWDNT
                PWD = 0
                PWDNT = 0
            END IF
        ELSE
            IF N = 28 THEN
                PRINT #6, USING "###"; SPC(2); MONTH; SPC(2); N; SPC(2); PWD; SPC(2); PWDNT
                PWD = 0
                PWDNT = 0
            END IF
        END IF
    END IF
    LOOP
    CLOSE #1
    CLOSE #2
    CLOSE #3
    CLOSE #4
    CLOSE #6
    PRINT "NUMBER OF YEARS SIMULATED:"; SPC(2); YEARCOUNT

```

```

/***** STARTS THE PWD TABLE PROCESS *****/
/VARIABLES:

```

```

'MONTH1 TO MONTH12 = ARE USED IN THE TEMPORARY FILES TO READ THE MONTHS.
'N1 TO N12 = ARE USED IN THE TEMPORARY FILES TO READ THE DAYS ON THE MONTHS.
'PT1 TO PT12 = ARE USED IN THE TEMPORARY FILES TO READ THE TILLAGE OPEARCTIONS ON THE MONTHS.
'PTN1 TO PTN12 = ARE USED IN THE TEMPORARY FILES TO READ THE NON-TILLAGE OPEARCTIONS ON THE
'MONTHS.
'MNTOT%() = TOTAL OF CALENDAR DAYS FOR EACH MONTH.
'TILLTOT%() = TOTAL OF TILLAGE WORKING DAYS PER MONTH
'NONTILLTOT%() = TOTAL OF NON-TILLAGE WORKING DAYS PER MONTH
'MONEXTEND$() = USED TO IDENTIFY EACH MONTH IN THE PWD TABLE PRINTOUT
'MONEXT$() = USED TO IDENTIFY THE EXTENSION OF TEMPORARY FILES FOR EACH MONTH
'SUMNTOT8% = TOTAL OF CALENDAR DAYS FOR THE FIRST 8 SORTED MONTH
'SUMNTOT12% = TOTAL OF CALENDAR DAYS FOR THE FIRST 12 SORTED MONTH
'SUMTILLTOT% = TOTAL OF WORKING DAYS FOR TILLAGE OPERATIONS
'SUMNONTILLTOT% = TOTAL OF WORKING DAYS FOR NON-TILLAGE OPERATIONS
'PWDTILLEND8!() = MONTHLY PWD COMPUTED FOR TILLAGE OPERATIONS USING 8 YEARS OUT OF 16
'PWDTILLEND12!() = MONTHLY PWD COMPUTED FOR TILLAGE OPERATIONS USING 12 YEARS OUT OF 16
'PWDTILLEND15!() = MONTHLY PWD COMPUTED FOR TILLAGE OPERATIONS USING 15 YEARS OUT OF 16
'PWDNONTILLEND8!() = MONTHLY PWD COMPUTED FOR NON-TILLAGE OPERATIONS USING 8 YEARS OUT OF 16
'PWDNONTILLEND12!() = MONTHLY PWD COMPUTED FOR NON-TILLAGE OPERATIONS USING 12 YEARS OUT
'OF 16
'PWDNONTILLEND15!() = MONTHLY PWD COMPUTED FOR NON-TILLAGE OPERATIONS USING 15 YEARS OUT
'OF 16
DIM MONEXT$(12)
OPEN DRIVE$ + RUN$ + ".JAN" FOR OUTPUT AS #1
OPEN DRIVE$ + RUN$ + ".FEB" FOR OUTPUT AS #2
OPEN DRIVE$ + RUN$ + ".MAR" FOR OUTPUT AS #3
OPEN DRIVE$ + RUN$ + ".APR" FOR OUTPUT AS #4
OPEN DRIVE$ + RUN$ + ".MAY" FOR OUTPUT AS #5
OPEN DRIVE$ + RUN$ + ".JUN" FOR OUTPUT AS #6
OPEN DRIVE$ + RUN$ + ".JUL" FOR OUTPUT AS #7
OPEN DRIVE$ + RUN$ + ".AUG" FOR OUTPUT AS #8
OPEN DRIVE$ + RUN$ + ".SEP" FOR OUTPUT AS #9
OPEN DRIVE$ + RUN$ + ".OCT" FOR OUTPUT AS #10
OPEN DRIVE$ + RUN$ + ".NOV" FOR OUTPUT AS #11
OPEN DRIVE$ + RUN$ + ".DEC" FOR OUTPUT AS #12
OPEN DRIVE$ + RUN$ + ".PWD" FOR INPUT AS #25
PRINT #1, "JAN."
PRINT #2, "FEB."
PRINT #3, "MAR."
PRINT #4, "APR."
PRINT #5, "MAY"
PRINT #6, "JUN."
PRINT #7, "JUL."
PRINT #8, "AUG."
PRINT #9, "SEP."
PRINT #10, "OCT."
PRINT #11, "NOV."
PRINT #12, "DEC."

/***** STARTS TO CREATE TEMPORARY FILES *****/
/***** FROM THE PREVIOUS FILE TO ORDER *****/
/***** THE DATA BASED ON THE YEAR *****/

DO UNTIL EOF(25)
  INPUT #25, YEAR
  INPUT #25, MONTH1, N1, PT1, PTN1
  INPUT #25, MONTH2, N2, PT2, PTN2
  INPUT #25, MONTH3, N3, PT3, PTN3
  INPUT #25, MONTH4, N4, PT4, PTN4
  INPUT #25, MONTH5, N5, PT5, PTN5
  INPUT #25, MONTH6, N6, PT6, PTN6
  INPUT #25, MONTH7, N7, PT7, PTN7
  INPUT #25, MONTH8, N8, PT8, PTN8
  INPUT #25, MONTH9, N9, PT9, PTN9
  INPUT #25, MONTH10, N10, PT10, PTN10
  INPUT #25, MONTH11, N11, PT11, PTN11
  INPUT #25, MONTH12, N12, PT12, PTN12
  PRINT #1, YEAR; N1; PT1; PTN1
  PRINT #2, YEAR; N2; PT2; PTN2
  PRINT #3, YEAR; N3; PT3; PTN3
  PRINT #4, YEAR; N4; PT4; PTN4
  PRINT #5, YEAR; N5; PT5; PTN5
  PRINT #6, YEAR; N6; PT6; PTN6
  PRINT #7, YEAR; N7; PT7; PTN7
  PRINT #8, YEAR; N8; PT8; PTN8
  PRINT #9, YEAR; N9; PT9; PTN9
  PRINT #10, YEAR; N10; PT10; PTN10
  PRINT #11, YEAR; N11; PT11; PTN11

```

```

PRINT #12, YEAR; N12; PT12; PTN12
LOOP
CLOSE #1
CLOSE #2
CLOSE #3
CLOSE #4
CLOSE #5
CLOSE #6
CLOSE #7
CLOSE #8
CLOSE #9
CLOSE #10
CLOSE #11
CLOSE #12

/***** STARTS TO CREATE SEPARATE TEMPORARY FILES FOR *****/
/***** TILLAGE AND NON-TILLAGE OPERATIONS AND FOR EACH MONTH *****/
/***** WITH THE SORTED DATA *****/

DIM mntot%(16), tilltot%(16), nontilltot%(16)
DIM monext$(12), PWDTILLEND8!(12), PWDtillend12!(12), PWDnontillend8!(12),
PWDnontillend12!(12), PWDnontillend15!(12), PWDnontillend15!(12),
DIM yr%(16), D%(16, 3)
MONEXT$(1) = ".jan"
MONEXT$(2) = ".feb"
MONEXT$(3) = ".mar"
MONEXT$(4) = ".apr"
MONEXT$(5) = ".may"
MONEXT$(6) = ".jun"
MONEXT$(7) = ".jul"
MONEXT$(8) = ".aug"
MONEXT$(9) = ".sep"
MONEXT$(10) = ".oct"
MONEXT$(11) = ".nov"
MONEXT$(12) = ".dec"
FOR i% = 1 TO 12
  OPEN DRIVE$ + RUN$ + MONEXT$(i%) FOR INPUT AS #i%
NEXT i%
FOR i% = 1 TO 12
  INPUT #i%, MN$
  FOR j% = 1 TO 16
    INPUT #i%, yr%(j%), D%(j%, 1), D%(j%, 2), D%(j%, 3)
  NEXT j%
  CLOSE (i%)

/***** SORTS NOW TILLAGE OPEARTIONS *****/

  CALL SortSI2N(D%(), 16, 2)

/***** CREATES TEMPORARY FILES WITH SORTED *****/
/***** DATA FOR TILLAGE OPERATIONS *****/

  OPEN DRIVE$ + RUN$ + "1" + MONEXT$(i%) FOR OUTPUT AS #i%
  FOR j% = 16 TO 1 STEP -1
    PRINT #i%, D%(j%, 1), D%(j%, 2)
  NEXT j%
  CLOSE (i%)

/***** SORTS NOW NON-TILLAGE OPEARTIONS *****/

  CALL SortSI2N(D%(), 16, 3)

/***** CREATES TEMPORARY FILES WITH SORTED *****/
/***** DATA FOR NON-TILLAGE OPERATIONS *****/

  OPEN DRIVE$ + RUN$ + "2" + MONEXT$(i%) FOR OUTPUT AS #i%
  FOR j% = 16 TO 1 STEP -1
    PRINT #i%, D%(j%, 1), D%(j%, 3)
  NEXT j%
  CLOSE (i%)
NEXT i%

/***** STARTS THE PWD COMPUTATIONS *****/

FOR i% = 1 TO 12
  OPEN DRIVE$ + RUN$ + "1" + MONEXT$(i%) FOR INPUT AS #i%
  FOR j% = 1 TO 16
    INPUT #i%, mntot%(j%), tilltot%(j%)

```

```

NEXT j%
CLOSE (i%)
sumntot8% = 0
sumtilltot% = 0
FOR j% = 1 TO 8
    sumntot8% = sumntot8% + mntot%(j%)
    sumtilltot% = sumtilltot% + tilltot%(j%)
NEXT j%
PWTILLEND8!(i%) = sumtilltot% / sumntot8%
sumntot12% = 0
sumtilltot% = 0
FOR j% = 1 TO 12
    sumntot12% = sumntot12% + mntot%(j%)
    sumtilltot% = sumtilltot% + tilltot%(j%)
NEXT j%
PWTILLEND12!(i%) = sumtilltot% / sumntot12%
sumntot15% = 0
sumtilltot% = 0
FOR j% = 1 TO 15
    sumntot15% = sumntot15% + mntot%(j%)
    sumtilltot% = sumtilltot% + tilltot%(j%)
NEXT j%
PWTILLEND15!(i%) = sumtilltot% / sumntot15%
NEXT i%
FOR i% = 1 TO 12
    OPEN DRIVE$ + RUN$ + "2" + MONEXT$(i%) FOR INPUT AS #i%
    FOR j% = 1 TO 16
        INPUT #i%, mntot%(j%), nontilltot%(j%)
    NEXT j%
    CLOSE (i%)
    sumntot8% = 0
    sumnontilltot% = 0
    FOR j% = 1 TO 8
        sumntot8% = sumntot8% + mntot%(j%)
        sumnontilltot% = sumnontilltot% + nontilltot%(j%)
    NEXT j%
    PWDnontillEND8!(i%) = sumnontilltot% / sumntot8%
    sumntot12% = 0
    sumnontilltot% = 0
    FOR j% = 1 TO 12
        sumntot12% = sumntot12% + mntot%(j%)
        sumnontilltot% = sumnontilltot% + nontilltot%(j%)
    NEXT j%
    PWDnontillEND12!(i%) = sumnontilltot% / sumntot12%
    sumntot15% = 0
    sumnontilltot% = 0
    FOR j% = 1 TO 15
        sumntot15% = sumntot15% + mntot%(j%)
        sumnontilltot% = sumnontilltot% + nontilltot%(j%)
    NEXT j%
    PWDnontillEND15!(i%) = sumnontilltot% / sumntot15%
NEXT i%
monextend$(1) = "Jan"
monextend$(2) = "Feb"
monextend$(3) = "Mar"
monextend$(4) = "Apr"
monextend$(5) = "May"
monextend$(6) = "Jun"
monextend$(7) = "Jul"
monextend$(8) = "Aug"
monextend$(9) = "Sep"
monextend$(10) = "Oct"
monextend$(11) = "Nov"
monextend$(12) = "Dec"

***** PRINTS NOW PWD TABLE *****

OPEN DRIVE$ + RUN$ + ".tbl" FOR OUTPUT AS #1
PRINT #1,
PRINT #1, "PROBABILITY OF WORKING DAYS TABLE FOR "; DRIVE$; SPC(0); RUN$; SPC(0); ".TBL"
PRINT #1,
PRINT #1, "USING WEATHER DATA INPUTFILE "; DRIVE$; SPC(0); WEATHER$; SPC(0); ".IN"
PRINT #1, "SELECTIONS FOR THIS RUN ARE:"
PRINT #1, "      1. CROP ..... "; SPC(1); CROP$
PRINT #1, "      2. PERMANENT WILTING POINT ..... "; : PRINT #1, USING "###.#";
      SPC(0); WP; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      3. FIELD CAPACITY ..... "; : PRINT #1, USING "###.#";

```

```

      SPC(0); FC; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      4. INITIAL MOISTURE CONTENT ..... "; : PRINT #1, USING "##.#";
      SPC(0); STMOIST; SPC(0); : PRINT #1, " mm/150mm"
PRINT #1, "      5. CRITERION FOR TILLAGE OPERATIONS ..... "; SPC(0); T; SPC(0); "%"
PRINT #1, "      6. CRITERION FOR NON-TILLAGE OPERATIONS .. "; SPC(0); O; SPC(0); "%"
IF CROP = 1 THEN GOTO PWDTBL1
IF CROP = 2 THEN GOTO PWDTBL2
PWDTBL1:
PRINT #1, "-----"
PRINT #1, "              PROBABILITY OF WORKING DAYS"
PRINT #1, "              FOR DIFFERENT FIELD OPERATIONS"
PRINT #1, "-----"
PRINT #1, "      MONTH      TILLAGE      NON TILLAGE"
PRINT #1, "-----"
PRINT #1, "              PROBABILITY LEVEL      PROBABILITY LEVEL"
PRINT #1, "-----"
PRINT #1, "              .50   .75   .94   .50   .75   .94  "
PRINT #1, "-----"
GOTO MAKETABLE
PWDTBL2:
PRINT #1, "-----"
PRINT #1, "              PROBABILITY OF WORKING DAYS"
PRINT #1, "              FOR SUGARCANE HARVESTING OPERATIONS"
PRINT #1, "-----"
PRINT #1, "      MONTH      PROBABILITY LEVEL"
PRINT #1, "-----"
PRINT #1, "              .50   .75   .94  "
PRINT #1, "-----"
MAKETABLE:
FOR i% = 1 TO 12
  MONTH = i%
  IF OPERMONTH1 = 1 THEN
    IF MONTH = 1 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH1 = 2 THEN
    IF MONTH = 1 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH2 = 1 THEN
    IF MONTH = 2 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH2 = 2 THEN
    IF MONTH = 2 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH3 = 1 THEN
    IF MONTH = 3 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH3 = 2 THEN
    IF MONTH = 3 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH4 = 1 THEN
    IF MONTH = 4 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH4 = 2 THEN
    IF MONTH = 4 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH5 = 1 THEN
    IF MONTH = 5 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH5 = 2 THEN
    IF MONTH = 5 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH6 = 1 THEN
    IF MONTH = 6 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH6 = 2 THEN
    IF MONTH = 6 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH7 = 1 THEN
    IF MONTH = 7 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH7 = 2 THEN
    IF MONTH = 7 THEN OPERMONTH = 2
  END IF
  IF OPERMONTH8 = 1 THEN
    IF MONTH = 8 THEN OPERMONTH = 1
  END IF
  IF OPERMONTH8 = 2 THEN
    IF MONTH = 8 THEN OPERMONTH = 2
  END IF

```

```

END IF
IF OPERMONTH9 = 1 THEN
  IF MONTH = 9 THEN OPERMONTH = 1
END IF
IF OPERMONTH9 = 2 THEN
  IF MONTH = 9 THEN OPERMONTH = 2
END IF
IF OPERMONTH10 = 1 THEN
  IF MONTH = 10 THEN OPERMONTH = 1
END IF
IF OPERMONTH10 = 2 THEN
  IF MONTH = 10 THEN OPERMONTH = 2
END IF
IF OPERMONTH11 = 1 THEN
  IF MONTH = 11 THEN OPERMONTH = 1
END IF
IF OPERMONTH11 = 2 THEN
  IF MONTH = 11 THEN OPERMONTH = 2
END IF
IF OPERMONTH12 = 1 THEN
  IF MONTH = 12 THEN OPERMONTH = 1
END IF
IF OPERMONTH12 = 2 THEN
  IF MONTH = 12 THEN OPERMONTH = 2
END IF
  IF CROP = 1 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1,
      PRINT #1, SPC(3); monextend$(i%); SPC(7); : PRINT #1, USING "#.##";
      PWDtillend8!(i%); SPC(9); PWDtillend12!(i%); SPC(9); PWDtillend15!(i%)
      : PRINT #1, " -- "; SPC(9); " -- "; SPC(9); "--"
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1,
      PRINT #1, SPC(3); monextend$(i%); SPC(7); : PRINT #1, " -- "; SPC(9); "--"
      SPC(9); " -- "; : PRINT #1, USING "#.##"; SPC(9); PWDnontillend8!(i%);
      SPC(9); PWDnontillend12!(i%); PWDnontillend15!(i%)
    END IF
  END IF
  IF CROP = 2 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1,
      PRINT #1, SPC(3); monextend$(i%); SPC(10); : PRINT #1, USING "#.##"; SPC(9);
      PWDnontillend8!(i%); SPC(9); PWDnontillend12!(i%); PWDnontillend15!(i%)
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1,
      PRINT #1, SPC(3); monextend$(i%); SPC(19); " -- "; SPC(9); " -- " ; SPC(9);
      " --"
    END IF
  END IF
NEXT i%
PRINT #1, "-----"
CLOSE (1)
END

```

***** SUBROUTINE SortSI2N *****

```

SUB SortSI2N (Num2Array%, RowCount%, SortCol%)
  ColSize% = UBOUND(Num2Array%, 2)
  DIM ThisRow!(ColSize%)
  IF RowCount% <= 1 THEN EXIT SUB
  FOR j% = 2 TO RowCount%
    FOR T% = 1 TO ColSize%
      ThisRow!(T%) = Num2Array%(j%, T%)
    NEXT T%
    K% = j% - 1
    WHILE (ThisRow!(SortCol%) < Num2Array%(K%, SortCol%)) AND (K% > 0)'Mod. #1
      FOR T% = 1 TO ColSize%
        Num2Array%(K% + 1, T%) = Num2Array%(K%, T%)
      NEXT T%
      K% = K% - 1
    WEND
    FOR T% = 1 TO ColSize%
      Num2Array%(K% + 1, T%) = ThisRow!(T%)
    NEXT T%
  NEXT j%
END SUB

```

2. Modified Tulu et al. (1974) model.

'THIS SIMULATION PROGRAM CAN BE USED TO COMPUTE
'PROBABILITIES OF WORKING DAYS (PWD) FOR MACHINE OPERATIONS
'BASED ON THE SOIL MOISTURE CONTENT IN THE FIRST 150 mm LAYER
'AS A FUNCTION OF WEATHER DATA FOR THE SOUTH COAST OF PUERTO RICO.
,PWD MODEL DEVELOPED BY TULU et al. (1974) AND OTHERS IS USED AS A REFERENCE ON THIS
STUDY.

'THIS MODEL COMPUTES PWD FOR TLLAGE AND NON-TILLAGE OPERATIONS ON VEGETABLES
'OR SUGARCANE HARVESTING OPERATIONS.

'WRITTEN BY CARLOS I. SEMIDEI.
1993

'VARIABLES:

'THE NEXT VARIABLES DIFFER FROM THE MODEL DEVELOPED BY HUNT
'(SEE MODEL DEVELOPED BY HUNT)

'FC1 TO FC3 = FIELD CAPACITIES FOR LAYERS 1 TO 3
'WP1 TO WP 3 = PERMANENT WILTING POINTS FOR LAYERS 1 TO 3
'DRN1 TO DRN3 = DRAINAGE COEFFICIENTS FOR LAYERS 1 TO 3
'T1 TO T3 = TILLAGE OPERATIONS WORKING DAY CRITERION
'TN1 TO TN3 = NON-TILLAGE OPERATIONS WORKING DAY CRITERION
'IMOIST1 TO IMOIST3 = INITIAL MOISTURE CONTENT DURING THE SIMULATION PROCESS
' FOR LAYERS 1 TO 3
'ET1 TO ET3 = EVAPOTRANSPIRATION FROM LAYERS 1 TO 3 DURING DAY N
'K1 TO K3 = EVAPORATION COEFFICIENTS FOR LAYERS 1 TO 3
'DRAIN1 TO DRAIN3 = DRAINAGE FORM LAYERS 1 TO 3 DURING DAY N
'CHMOIST1 TO CHMOIST3 = CHANGE IN SOIL MOISTURE AFTER ET FOR LAYERS 1 TO 3
'WATERINF1 = WATER INFILATRTION INTO LAYER 1 DURING DAY N
'RCHMOIST1 TO RCHMOIST3 = CHANGE OF SOIL MOISTURE AFTER DRAINAGE ON LAYERS 1 TO 3
' DURING DAY N
'MOIST1 TO MOIST3 = SOIL MOISTURE CONTENT IN LAYERS 1 TO 3 DURING DAY N
'TOTMOIST = SOIL MOISTURE CONTENT FOR THE 150 mm LAYER.
'WT1 TO WT3 = SOIL MOISTURE CRITERIA FOR TILLAGE OPERATIONS FOR LAYERS 1 TO 3
'WTN1 TO WTN3 = SOIL MOISTURE CRITERIA FOR NON-TILLAGE OPERATIONS FOR LAYERS 1 TO 3
'ZONET1 TO ZONET3 = WORKING OR NON-WORKING DAY DEFINITION FOR TILLAGE OPERATIONS IN
' LAYERS 1 TO 3 DURING DAY N
'ZONETN1 TO ZONETN3 = WORKING OR NON-WORKING DAY DEFINITION FOR NON-TILLAGE OPERATIONS IN
' LAYERS 1 TO 3 DURING DAY N
,
'TOTZONET = WORKING OR NON-WORKING DAY FINAL DEFINITION FOR TILLAGE OPERATIONS
' DURING DAY N
'TOTZONETN = WORKING OR NON-WORKING DAY FINAL DEFINITION FOR NON-TILLAGE OPERATIONS
' DURING DAY N

***** DEFAULT VARIABLES *****

CLS
STMOIST = 30
FC = 45
WP = 25
FCL1 = FC * .2
FCL2 = FC * .3
FCL3 = FC * .5
WPL1 = WP * .2
WPL2 = WP * .3
WPL3 = WP * .5
DRN1 = 1
DRN2 = 1
DRN3 = 1
RNC = 1
T1 = 95
T2 = 95
T3 = 99
TN1 = 98
TN2 = 99
TN3 = 99

DRAINDEC:

CLS

***** SELECTION OF DRAINAGE COEFFICENTS FOR EACH LAYER *****

PRINT " WATER IS ASSUMED TO DRAIN WHEN SOIL MOISTURE CONTENT "
PRINT " IS GREATER THEN FIELD CAPACITY IN ANY LAYER."
PRINT " WATER DOES NOT DRAIN COMPLETILY DURING THE DAY OF COMPUTATION. "
PRINT " A DRAINAGE COEFFICIENT (DRN) CAN ADJUST THE AMOUNT OF WATER"
PRINT " THAT IS ABLE TO DRAIN PER DAY. DRN IS ASSUMED IN THIS STUDY AS:"
PRINT " LAYER 1 = "; DRN1
PRINT " LAYER 2 = "; DRN2
PRINT " LAYER 3 = "; DRN3

```

INPUT "DO YOU WANT TO CHANGE DRAINAGE COEFFICIENT? (Y/N)"; DRN$
IF DRN$ = "Y" THEN GOTO DRNCHN
IF DRN$ = "N" THEN GOTO SOILMDEC
DRNCHN:
INPUT "ENTER NEW DRAINAGE COEFFICIENT FOR LAYER 1: ", DRN1
INPUT "ENTER NEW DRAINAGE COEFFICIENT FOR LAYER 2: ", DRN2
INPUT "ENTER NEW DRAINAGE COEFFICIENT FOR LAYER 3: ", DRN3
PRINT "PRESS ANY KEY TO CONTINUE"
WHILE INKEY$ = "": WEND

```

***** SELECTION OF FIELD OPERATION CRITERIA *****

```

SOILMDEC:
PRINT "A DAY IS ASSUMED TO BE SUITABLE FOR TILLAGE OPERATIONS (PLOW, ETC)"
PRINT "WHEN THE SOIL MOISTURE CONTENT IS:"
PRINT "      1. LESS THAN"; T1; "% OF THE FIELD CAPACITY IN LAYER 1"
PRINT "      2. LESS THAN"; T2; "% OF THE FIELD CAPACITY IN LAYER 2"
PRINT "      3. LESS THAN"; T3; "% OF THE FIELD CAPACITY IN LAYER 3"
PRINT "A DAY IS ASSUMED TO BE SUITABLE FOR NON TILLAGE OPERATIONS (SPRAYING, ETC.)"
PRINT "WHEN THE SOIL MOISTURE CONTENT IS:"
PRINT "      1. LESS THAN"; TN1; "% OF THE FIELD CAPACITY IN LAYER 1"
PRINT "      2. LESS THAN"; TN2; "% OF THE FIELD CAPACITY IN LAYER 3"
PRINT "      3. LESS THAN"; TN3; "% OF THE FIELD CAPACITY IN LAYER 3"
INPUT "DO YOU WANT TO CHANGE ANY OF THESE PERCENTAGES? (Y/N)", K$
IF K$ = "Y" GOTO SELPER
IF K$ = "N" GOTO COMPUTATIONS
SELPER:
CLS
PRINT "WHICH PERCENTAGE DO YOU WANT TO CHANGE?"
PRINT "      1. FOR TILLAGE OPERATIONS LAYER 1 ("; SPC(0); T1; SPC(0); "%)"
PRINT "      2. FOR TILLAGE OPERATIONS LAYER 2 ("; SPC(0); T2; SPC(0); "%)"
PRINT "      3. FOR TILLAGE OPERATIONS LAYER 3 ("; SPC(0); T3; SPC(0); "%)"
PRINT "      4. FOR NON TILLAGE OPERATIONS LAYER 1 ("; SPC(0); TN1; SPC(0); "%)"
PRINT "      5. FOR NON TILLAGE OPERATIONS LAYER 2 ("; SPC(0); TN2; SPC(0); "%)"
PRINT "      6. FOR NON TILLAGE OPERATIONS LAYER 3 ("; SPC(0); TN3; SPC(0); "%)"
INPUT K
IF K = 1 THEN GOTO TILLAGE1
IF K = 2 THEN GOTO TILLAGE2
IF K = 3 THEN GOTO TILLAGE3
IF K = 4 THEN GOTO NONTILLAGE1
IF K = 5 THEN GOTO NONTILLAGE2
IF K = 6 THEN GOTO NONTILLAGE3
IF K THEN ELSE
  PRINT "INPUT ERROR DETECTED....."
  PRINT "SELECTION SHOULD BE 1 TO 6"
  PRINT "TRY AGAIN"
  GOTO SELPER
TILLAGE1:
INPUT "ENTER NEW PERCENT FOR TILLAGE OPERATIONS LAYER 1: ", T1
GOTO SELPER2
TILLAGE2:
INPUT "ENTER NEW PERCENT FOR TILLAGE OPERATIONS LAYER 2: ", T2
GOTO SELPER2
TILLAGE3:
INPUT "ENTER NEW PERCENT FOR TILLAGE OPERATIONS LAYER 3: ", T3
GOTO SELPER2
NONTILLAGE1:
INPUT "ENTER NEW PERCENT FOR NON TILLAGE OPERATIONS LAYER 1: ", TN1
GOTO SELPER2
NONTILLAGE2:
INPUT "ENTER NEW PERCENT FOR NON TILLAGE OPERATIONS LAYER 2: ", TN2
GOTO SELPER2
NONTILLAGE3:
INPUT "ENTER NEW PERCENT FOR NON TILLAGE OPERATIONS LAYER 3: ", TN3
GOTO SELPER2
SELPER2:
INPUT "DO YOU WANT TO CHANGE ANOTHER ONE? (Y/N)", CH$
IF CH$ = "Y" THEN GOTO SELPER
IF CH$ = "N" THEN GOTO COMPUTATIONS

```

***** ENDS SELECTIONS FOR THE RUN *****

```

COMPUTATIONS:
IMOIST = STMOIST
IMOIST1 = IMOIST * .2
IMOIST2 = IMOIST * .3
IMOIST3 = IMOIST * .5
CLS

```

*****SHOWS SELECTIONS FOR THE SIMULATION *****

```

PRINT "SELECTIONS FOR THIS RUN ARE:"
PRINT "  1. WILTING POINT "; SPC(0); WP; SPC(0); "mm/150mm"
PRINT "  2. FIELD CAPACITY "; SPC(0); FC; SPC(0); "mm/150mm"
PRINT "  3. INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(0); "mm/150mm "
PRINT "  4. DRAINAGE COEFFICIENT FOR LAYER 1: "; DRN1
PRINT "  5. DRAINAGE COEFFICIENT FOR LAYER 2: "; DRN2
PRINT "  6. DRAINAGE COEFFICIENT FOR LAYER 3: "; DRN3
PRINT "  SOIL MOISTURE PERCENT TO AFFECT OPERATIONS:"
PRINT "  8. FOR TILLAGE OPERATIONS LAYER 1 "; SPC(0); T1; SPC(0); "% "
PRINT "  9. FOR TILLAGE OPERATIONS LAYER 2 "; SPC(0); T2; SPC(0); "% "
PRINT " 10. FOR TILLAGE OPERATIONS LAYER 3 "; SPC(0); T3; SPC(0); "% "
PRINT " 11. FOR NON TILLAGE OPERATIONS LAYER 1 "; SPC(0); TN1; SPC(0); "% "
PRINT " 12. FOR NON TILLAGE OPERATIONS LAYER 2 "; SPC(0); TN2; SPC(0); "% "
PRINT " 13. FOR NON TILLAGE OPERATIONS LAYER 3 "; SPC(0); TN3; SPC(0); "% "
INPUT "TYPE NAME OF OUTPUT FILE FOR THIS RUN: ", RUN$
PRINT "TYPE FILENAME IDENTIFICATION OF THE WEATHER DATA INPUT FILE"
INPUT "THAT YOU WANT TO USE FOR THIS RUN (WITH NO EXTENSION PLEASE):", WEATHER$
PRINT "HOW DO YOU WANT TO RANK THE OUTPUT FILE?"
PRINT "  1. DAILY SUMMARIES"
PRINT "  2. BIMONTHLY SUMMARIES"
PRINT "  3. MONTHLY SUMMARIES"
INPUT ; OUTF
CLS
PRINT "NOW I'M SIMULATING .....PLEASE WAIT"
OPEN DRIVE$ + WEATHER$ + ".IN" FOR INPUT AS #4
  INPUT #4, YEAR
  INPUT #4, MONTH, N
  PRINT "SIMULATING NOW"
  PRINT YEAR
IF OUTF = 1 THEN
  OPEN DRIVE$ + RUN$ + ".DAY" FOR OUTPUT AS #1
  PRINT #1, "OUTPUT RUNNING TULU ET. AL. MODEL"
  PRINT #1, "PRINT OUTPUT FOR "; DRIVE$; SPC(0); RUN$; SPC(0); ".DAY"
  PRINT #1, "USING WEATHER DATA INPUTFILE "; DRIVE$; SPC(0); WEATHER$; SPC(0); ".IN"
  PRINT #1, "INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(1); "mm/150mm"
  PRINT #1, "INITIAL MOISTURE CONTENT ZONE 1: "; SPC(0); IMOIST1; SPC(1); "mm/50mm"
  PRINT #1, "INITIAL MOISTURE CONTENT ZONE 2: "; SPC(0); IMOIST2; SPC(1); "mm/50mm"
  PRINT #1, "INITIAL MOISTURE CONTENT ZONE 3: "; SPC(0); IMOIST3; SPC(1); "mm/150m"
  PRINT #1, "SELECTIONS FOR THIS RUN:"
  PRINT #1, "  1. WILTING POINT "; SPC(0); WP; SPC(0); "mm/150mm"
  PRINT #1, "  2. FIELD CAPACITY "; SPC(0); FC; SPC(0); "mm/150mm"
  PRINT #1, "  3. INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(0); "mm/150mm)"
  PRINT #1, "  4. RUNOFF COEFFICIENT "; RNC
  PRINT #1, "  5. DRAINAGE COEFFICIENT FOR LAYER 1: ", DRN1
  PRINT #1, "  6. DRAINAGE COEFFICIENT FOR LAYER 2: ", DRN2
  PRINT #1, "  7. DRAINAGE COEFFICIENT FOR LAYER 3: ", DRN3
  PRINT #1, "  SOIL MOISTURE PERCENT TO AFFECT OPERATIONS:"
  PRINT #1, "  8. FOR TILLAGE OPERATIONS LAYER 1 ( "; SPC(0); T1; SPC(0); "%)"
  PRINT #1, "  9. FOR TILLAGE OPERATIONS LAYER 2 ( "; SPC(0); T2; SPC(0); "%)"
  PRINT #1, " 10. FOR TILLAGE OPERATIONS LAYER 3 ( "; SPC(0); T3; SPC(0); "%)"
  PRINT #1, " 11 FOR NON TILLAGE OPERATIONS LAYER 1 ( "; SPC(0); TN1; SPC(0); "%)"
  PRINT #1, " 12. FOR NON-TILLAGE OPERATIONS LAYER 2 ( "; SPC(0); TN2; SPC(0); "%)"
  PRINT #1, " 13. FOR NON-TILLAGE OPERATIONS LAYER 3 ( "; SPC(0); TN3; SPC(0); "%)"
  PRINT #1, "-----"
  PRINT #1, " DATE : PET :      E T      : RN RO :  DRAINAGE :  SOIL MOISTURE :  WORK"
  PRINT #1, "-----"
  PRINT #1, "MON DAY:      : FROM LAYER :      : (FROM-TO) :  LAYER :TOT:"
  PRINT #1, "      :      : 1  2  3 :      : 1-2:2-3:3-4 :  1  2  3 :  : TL NTL"
  PRINT #1, "-----"
  PRINT #1, YEAR
END IF

```

***** STARTS COMPUTATIONS OF SOIL MOISTURE CONTENT *****

```

DO UNTIL EOF(4)
  INPUT #4, MONTH, N, RAIN, EP

```

EVAPOTRANSPIRATION:

```

EP = (EP * 25.4) / 100' CONVERTS EP FROM HUNDREDTHS INCHES TO MILLIMETERS
KP = 0.8
PET = EP * KP

```

```

IF MONTH = 1 THEN ET = PET * KC1
IF MONTH = 2 THEN ET = PET * KC2
IF MONTH = 3 THEN ET = PET * KC3
IF MONTH = 4 THEN ET = PET * KC4
IF MONTH = 5 THEN ET = PET * KC5
IF MONTH = 6 THEN ET = PET * KC6
IF MONTH = 7 THEN ET = PET * KC7
IF MONTH = 8 THEN ET = PET * KC8
IF MONTH = 9 THEN ET = PET * KC9
IF MONTH = 10 THEN ET = PET * KC10
IF MONTH = 11 THEN ET = PET * KC11
IF MONTH = 12 THEN ET = PET * KC12
IF CROP = 1 THEN
  K1 = .55
  K2 = .40
  K3 = .05
END IF
IF CROP = 2 THEN
  K1 = .3
  K2 = .2
  K3 = .1
END IF
ET1 = ET * K1
ET2 = ET * K2
ET3 = ET * K3
IF IMOIST1 - ET1 < WPL1 THEN
  ET1 = IMOIST1 - WPL1
  IF ET1 < 0 THEN ET1 = 0
END IF
IF IMOIST2 - ET2 < WPL2 THEN
  ET2 = IMOIST2 - WPL2
  IF ET2 < 0 THEN ET2 = 0
END IF
IF IMOIST3 - ET3 < WPL3 THEN
  ET3 = IMOIST3 - WPL3
  IF ET3 < 0 THEN ET3 = 0
END IF
ETEND:
CHMOIST1 = IMOIST1 - ET1
CHMOIST2 = IMOIST2 - ET2
CHMOIST3 = IMOIST3 - ET3
CHMOIST = CHMOIST1 + CHMOIST2 + CHMOIST3
RUNOFF:
RAIN = RAIN * 25.4 'CONVERTS RAIN FROM INCHES TO MILLIMETERS
MAXSAT = FC * 1.15
S = (MAXSAT - CHMOIST) * RNC
IF RAIN = 0 THEN
  Q = 0
  GOTO RUNOFFEND
END IF
IF RAIN < .2 * S THEN
  Q = 0
  GOTO RUNOFFEND
END IF
IF CHMOIST > MAXSAT THEN
  Q = RAIN
  GOTO RUNOFFEND
END IF
IF RAIN > .2 * S THEN
  Q = (RAIN - (.2 * S)) ^ 2 / (RAIN + (.8 * S))
END IF
RUNOFFEND:
WATERINF1 = RAIN - Q
RCHMOIST1 = CHMOIST1 + WATERINF1
DRAINAGE:
IF RCHMOIST1 < FCL1 THEN DRAIN1 = 0
IF RCHMOIST1 > FCL1 THEN
  DRAIN1 = (RCHMOIST1 - FCL1) * DRN1
END IF
MOIST1 = RCHMOIST1 - DRAIN1
RCHMOIST2 = CHMOIST2 + DRAIN1
IF RCHMOIST2 < FCL2 THEN DRAIN2 = 0
IF RCHMOIST2 > FCL2 THEN
  DRAIN2 = (RCHMOIST2 - FCL2) * DRN2
END IF
MOIST2 = RCHMOIST2 - DRAIN2
RCHMOIST3 = CHMOIST3 + DRAIN2
IF RCHMOIST3 < FCL3 THEN DRAIN3 = 0

```

```

IF RCHMOIST3 > FCL3 THEN
  DRAIN3 = (RCHMOIST3 - FCL3) * DRN3
END IF
MOIST3 = RCHMOIST3 - DRAIN3
TOTMOIST = MOIST1 + MOIST2 + MOIST3

```

```

/ ***** DEFINES THE FIELD OPERATIONS BY MONTH AND CROP *****

```

```

IF OPERMONTH1 = 1 THEN
  IF MONTH = 1 THEN OPERMONTH = 1
END IF
IF OPERMONTH1 = 2 THEN
  IF MONTH = 1 THEN OPERMONTH = 2
END IF
IF OPERMONTH2 = 1 THEN
  IF MONTH = 2 THEN OPERMONTH = 1
END IF
IF OPERMONTH2 = 2 THEN
  IF MONTH = 2 THEN OPERMONTH = 2
END IF
IF OPERMONTH3 = 1 THEN
  IF MONTH = 3 THEN OPERMONTH = 1
END IF
IF OPERMONTH3 = 2 THEN
  IF MONTH = 3 THEN OPERMONTH = 2
END IF
IF OPERMONTH4 = 1 THEN
  IF MONTH = 4 THEN OPERMONTH = 1
END IF
IF OPERMONTH4 = 2 THEN
  IF MONTH = 4 THEN OPERMONTH = 2
END IF
IF OPERMONTH5 = 1 THEN
  IF MONTH = 5 THEN OPERMONTH = 1
END IF
IF OPERMONTH5 = 2 THEN
  IF MONTH = 5 THEN OPERMONTH = 2
END IF
IF OPERMONTH6 = 1 THEN
  IF MONTH = 6 THEN OPERMONTH = 1
END IF
IF OPERMONTH6 = 2 THEN
  IF MONTH = 6 THEN OPERMONTH = 2
END IF
IF OPERMONTH7 = 1 THEN
  IF MONTH = 7 THEN OPERMONTH = 1
END IF
IF OPERMONTH7 = 2 THEN
  IF MONTH = 7 THEN OPERMONTH = 2
END IF
IF OPERMONTH8 = 1 THEN
  IF MONTH = 8 THEN OPERMONTH = 1
END IF
IF OPERMONTH8 = 2 THEN
  IF MONTH = 8 THEN OPERMONTH = 2
END IF
IF OPERMONTH9 = 1 THEN
  IF MONTH = 9 THEN OPERMONTH = 1
END IF
IF OPERMONTH9 = 2 THEN
  IF MONTH = 9 THEN OPERMONTH = 2
END IF
IF OPERMONTH10 = 1 THEN
  IF MONTH = 10 THEN OPERMONTH = 1
END IF
IF OPERMONTH10 = 2 THEN
  IF MONTH = 10 THEN OPERMONTH = 2
END IF

IF OPERMONTH11 = 1 THEN
  IF MONTH = 11 THEN OPERMONTH = 1
END IF
IF OPERMONTH11 = 2 THEN
  IF MONTH = 11 THEN OPERMONTH = 2
END IF
IF OPERMONTH12 = 1 THEN
  IF MONTH = 12 THEN OPERMONTH = 1
END IF

```

```

IF OPERMONTH12 = 2 THEN
  IF MONTH = 12 THEN OPERMONTH = 2
END IF
IF MONTH = 12 THEN
  IF N = 31 THEN
    YEARCOUNT = YEARCOUNT + 1
  END IF
END IF

***** STARTS TO DEFINE IF THE DAY N IS OR NOT A WORKING DAY *****

DECISION:
  WT1 = (FCL1 * T1) / 100
  WT2 = (FCL2 * T2) / 100
  WT3 = (FCL3 * T3) / 100
  WTN1 = (FCL1 * TN1) / 100
  WTN2 = (FCL2 * TN2) / 100
  WTN3 = (FCL3 * TN3) / 100
  IF MOIST1 < WT1 THEN ZONET1 = 1
  IF MOIST2 < WT2 THEN ZONET2 = 1
  IF MOIST3 < WT3 THEN ZONET3 = 1
  IF MOIST1 > WT1 THEN ZONET1 = 0
  IF MOIST2 > WT2 THEN ZONET2 = 0
  IF MOIST3 > WT3 THEN ZONET3 = 0
  TOTZONET = ZONET1 + ZONET2 + ZONET3
  IF TOTZONET < 3 THEN WTV = 0
  IF TOTZONET = 3 THEN WTV = 1
  IF MOIST1 < WTN1 THEN ZONETN1 = 1
  IF MOIST2 < WTN2 THEN ZONETN2 = 1
  IF MOIST3 < WTN3 THEN ZONETN3 = 1
  IF MOIST1 > WTN1 THEN ZONETN1 = 0
  IF MOIST2 > WTN2 THEN ZONETN2 = 0
  IF MOIST3 > WTN3 THEN ZONETN3 = 0
  TOTZONETN = ZONETN1 + ZONETN2 + ZONETN3
  IF TOTZONETN < 3 THEN WTNV = 0
  IF TOTZONETN = 3 THEN WTNV = 1
  PWDT = PWDT + WTV
  PWDNT = PWDNT + WTNV
  TILL = TILL + WTV
  NTILL = NTILL + WTNV

***** STARTS PRINT OUTPUT FOR DAILY OPTIONS *****

IF OUTF = 1 THEN
  IF CROP = 1 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "####"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; SPC(2); MOIST1; SPC(1); MOIST2; SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); :
      PRINT #1, WTV; SPC(2); "-"
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "####"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; SPC(2); MOIST1; SPC(1); MOIST2; SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); :
      PRINT #1, "-"; SPC(2); WTNV
    END IF
  END IF
  IF CROP = 2 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "####"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; SPC(2); MOIST1; SPC(1); MOIST2; SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); :
      PRINT #1, "-"; SPC(2); WTNV
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "####"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; SPC(2); MOIST1; SPC(1); MOIST2; SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); :
      PRINT #1, "-"; SPC(2); "-"
    END IF
  END IF
END IF
IMOIST1 = MOIST1

```

```
IMOIST2 = MOIST2  
IMOIST3 = MOIST3
```

```
LOOP
```

3. Modified Babeir et al. (1986) model.

'THIS SIMULATION PROGRAM CAN BE USED TO COMPUTE
 'PROBABILITIES OF WORKING DAYS (PWD) FOR MACHINE OPERATIONS
 'BASED ON THE SOIL MOISTURE CONTENT IN THE FIRST 150 mm LAYER
 'AS A FUNCTION OF WEATHER DATA FOR THE SOUTH COAST OF PUERTO RICO.
 ,PWD MODEL DEVELOPED BY BABEIR et. al (1986) IS USED AS A REFERENCE ON THIS STUDY.
 'THIS MODEL COMPUTES PWD FOR TLLAGE AND NON-TILLAGE OPERATIONS ON VEGETABLES
 'OR SUGARCANE HARVESTING OPERATIONS.

'WRITTEN BY CARLOS I. SEMIDEI.
 1993

'VARIABLES:

'THE NEXT VARIABLES DIFFER FROM THE MODEL DEVELOPED BY
 'HUNT (1986) AND TULU et al. (1974) DUE TO THE ADDITION OF A FOURTH LAYER

'FCL = FIELD CAPACITY FOR EACH LAYER
 'WPL = PERMANENT WILTING POINT EACH LAYER
 'DRN = DRAINAGE COEFFICIENT
 'DFF = DIFFUSION COEFFICIENT
 'IMOIST4 = INITIAL MOISTURE CONTENT DURING THE SIMULATION PROCESS FOR LAYER 4
 'ET4 = EVAPOTRANSPIRATION FROM LAYER 4 DURING DAY N
 'K4 = EVAPORATION COEFFICIENT FOR LAYER 4
 'DRAIN4 = DRAINAGE FORM LAYER 4 DURING DAY N
 'CHMOIST4 = CHANGE IN SOIL MOISTURE AFTER ET FOR LAYER 4
 'RCHMOIST4 = CHANGE IN SOIL MOISTURE AFTER DRAINAGE IN LAYER 4 DURING DAY N
 'DRNCHMOIST1 TO DRNCHMOIST4 = CHANGE IN SOIL MOISTURE AFTER THE CESSATION OF DRAINAGE IN
 ' LAYERS 1 TO 4
 'DIFF12, DIFF23, AND DIFF34 = DIFFUSION BETWEEN THE RESPECTIVES LAYERS (1, 2, 3 AND, 4
 'MOIST4 = SOIL MOISTURE CONTENT IN LAYER 4 DURING DAY N

/'***** DEFAULT VARIABLES *****

CLS
 STMOIST = 30
 FC = 45
 WP = 25
 FCL = FC / 3
 WPL = WP / 3
 DRN = 1
 DFF = 1
 RNC = 1
 T1 = 95
 T2 = 95
 T3 = 99
 TN1 = 98
 TN2 = 99
 TN3 = 99

DIFFDEC:
 CLS

/'***** SELECTION OF DIFFUSION COEFFICIENT*****

'PRINT "IN THIS MODEL DIFFUSION BETWEEN LAYERS IS COMPUTED"
 'PRINT "THE RATE OF DIFFUSION IS ADJUSTED BY THE DIFFUSION" 'PRINT "COEFFICIENT THAT IS", DFF

INPUT "DO YOU WANT TO CHANGE IT (Y/N)?", CHNDF\$
 IF CHNDF\$ = "Y" THEN
 INPUT " ENTER DIFFUSION COEFFICIENT ", DFF
 IF CHNDF\$ = "N" THEN GOTO SELECTION

/'***** ENDS SELECTIONS FOR THE RUN *****

COMPUTATIONS:
 IMOIST = STMOIST
 IMOIST1 = IMOIST * .2
 IMOIST2 = IMOIST * .3
 IMOIST3 = IMOIST * .5
 IMOIST4 = IMOIST * .5
 CLS

***** SHOWS SELECTIONS FOR THE SIMULATION *****

PRINT "SELECTIONS FOR THIS RUN ARE:"
 PRINT " 1. WILTING POINT "; SPC(0); WP; SPC(0); "mm/150mm"

```

PRINT "      2. FIELD CAPACITY "; SPC(0); FC; SPC(0); "mm/150mm"
PRINT "      3. INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(0); "mm/150mm "
PRINT "      4. DRAINAGE COEFFICIENT: "; DRN
PRINT "      5. DIFFUSION COEFFICIENT: "; DFF
PRINT "      6. RUNOFF COEFFICIENT: "; RNC
PRINT "      SOIL MOISTURE PERCENT TO AFFECT OPERATIONS:"
PRINT "      8. FOR TILLAGE OPERATIONS LAYER 1 "; SPC(0); T1; SPC(0); "% "
PRINT "      9. FOR TILLAGE OPERATIONS LAYER 2 "; SPC(0); T2; SPC(0); "% "
PRINT "     10. FOR TILLAGE OPERATIONS LAYER 3 "; SPC(0); T3; SPC(0); "% "
PRINT "     11. FOR NON TILLAGE OPERATIONS LAYER 1 "; SPC(0); TN1; SPC(0); "% "
PRINT "     12. FOR NON TILLAGE OPERATIONS LAYER 2 "; SPC(0); TN2; SPC(0); "% "
PRINT "     13. FOR NON TILLAGE OPERATIONS LAYER 3 "; SPC(0); TN3; SPC(0); "% "
INPUT "TYPE NAME OF OUTPUT FILE FOR THIS RUN: ", RUN$
PRINT "TYPE FILENAME IDENTIFICATION OF THE WEATHER DATA INPUT FILE"
INPUT "THAT YOU WANT TO USE FOR THIS RUN (WITH NO EXTENSION PLEASE):", WEATHER$
PRINT "HOW DO YOU WANT TO RANK THE OUTPUT FILE?"
PRINT "  1. DAILY SUMMARIES"
PRINT "  2. BIMONTHLY SUMMARIES"
PRINT "  3. MONTHLY SUMMARIES"
INPUT ; OUTF
CLS
PRINT "NOW I'M SIMULATING .....PLEASE WAIT"

IF OUTF = 1 THEN
  OPEN DRIVE$ + RUN$ + ".DAY" FOR OUTPUT AS #1
  PRINT #1, "OUTPUT RUNNING TULU ET. AL. MODEL"
  PRINT #1, "PRINT OUTPUT FOR "; DRIVE$; SPC(0); RUN$; SPC(0); ".DAY"
  PRINT #1, "USING WEATHER DATA INPUTFILE "; DRIVE$; SPC(0); WEATHER$; SPC(0); ".IN"
  PRINT #1, "INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(1); "mm/150mm"
  PRINT #1, "INITIAL MOISTURE CONTENT LAYER 1 :"; SPC(0); IMOIST1; SPC(1); "mm/50mm"
  PRINT #1, "INITIAL MOISTURE CONTENT LAYER 2 :"; SPC(0); IMOIST2; SPC(1); "mm/50mm"
  PRINT #1, "INITIAL MOISTURE CONTENT LAYER 3 : "; SPC(0); IMOIST3; SPC(1); "mm/150mm"
  PRINT #1, "INITIAL MOISTURE CONTENT LAYER 4 : "; SPC(0); IMOIST4; SPC(1); "mm/150mm"
  PRINT #1, "SELECTIONS FOR THIS RUN:"
  PRINT #1, "      1. WILTING POINT "; SPC(0); WP; SPC(0); "mm/150mm"
  PRINT #1, "      2. FIELD CAPACITY "; SPC(0); FC; SPC(0); "mm/150mm"
  PRINT #1, "      3. INITIAL MOISTURE CONTENT "; SPC(0); STMOIST; SPC(0); "mm/150mm"
  PRINT #1, "      4. RUNOFF COEFFICIENT "; SPC(0); RNC
  PRINT #1, "      5. DRAINAGE COEFFICIENT";DRN
  PRINT #1, "      6. DIFFUSION COEFFICIENT";DFF
  PRINT #1, "      SOIL MOISTURE PERCENT TO AFFECT OPERATIONS:"
  PRINT #1, "      7. FOR TILLAGE OPERATIONS LAYER 1 ("; SPC(0); T1; SPC(0); "%)"
  PRINT #1, "      8. FOR TILLAGE OPERATIONS LAYER 2 ("; SPC(0); T2; SPC(0); "%)"
  PRINT #1, "      9. FOR TILLAGE OPERATIONS LAYER 3 ("; SPC(0); T3; SPC(0); "%)"
  PRINT #1, "     10 FOR NON TILLAGE OPERATIONS LAYER 1 ("; SPC(0); TN1; SPC(0); "%)"
  PRINT #1, "     11. FOR NON TILLAGE OPERATIONS LAYER 2 ("; SPC(0); TN2; SPC(0); "%)"
  PRINT #1, "     12. FOR NON TILLAGE OPERATIONS LAYER 3 ("; SPC(0); TN3; SPC(0); "%)"
  PRINT #1, "....."
  PRINT #1, "      ET      RAIN RO      DRAINAGE      DIFFUSION"
  PRINT #1, "      SOIL MOISTURE WORK"
  PRINT #1, "MN/DAY PET  1  2  3          1  2  3  1-2  2-3  3-4    1  2  3"
  PRINT #1, "TOT  T  NT"
  PRINT #1, ".....:"
  PRINT #1, YEAR
END IF

***** STARTS COMPUTATIONS OF SOIL MOISTURE CONTENT *****

DO UNTIL EOF(4)
  INPUT #4, MONTH, N, RAIN, EP
  EVAPOTRANSPIRATION:
  EP = (EP * 25.4) / 100' CONVERTS EP FROM HUNDREDTHS INCHES TO MILLIMETERS
  KP = 0.8
  PET = EP * KP
  IF MONTH = 1 THEN ET = PET * KC1
  IF MONTH = 2 THEN ET = PET * KC2
  IF MONTH = 3 THEN ET = PET * KC3
  IF MONTH = 4 THEN ET = PET * KC4
  IF MONTH = 5 THEN ET = PET * KC5
  IF MONTH = 6 THEN ET = PET * KC6
  IF MONTH = 7 THEN ET = PET * KC7
  IF MONTH = 8 THEN ET = PET * KC8
  IF MONTH = 9 THEN ET = PET * KC9
  IF MONTH = 10 THEN ET = PET * KC10
  IF MONTH = 11 THEN ET = PET * KC11
  IF MONTH = 12 THEN ET = PET * KC12
  IF CROP = 1 THEN

```

```

K1 = .6
K2 = .35
K3 = .05

K4 = 0
END IF
IF CROP = 2 THEN
  K1 = .3
  K2 = .2
  K3 = .1
  K4 = .1
END IF
ET1 = ET * K1
ET2 = ET * K2
ET3 = ET * K3
ET4 = ET * K4
IF IMOIST1 - ET1 < WPL THEN ET1 = IMOIST1 - WPL
IF IMOIST2 - ET2 < WPL THEN ET2 = IMOIST2 - WPL
IF IMOIST3 - ET3 < WPL THEN ET3 = IMOIST3 - WPL
IF IMOIST4 - ET4 < WPL THEN ET4 = IMOIST4 - WPL
ETEND:
CHMOIST1 = IMOIST1 - ET1
CHMOIST2 = IMOIST2 - ET2
CHMOIST3 = IMOIST3 - ET3
CHMOIST4 = IMOIST4 - ET4
CHMOIST = CHMOIST1 + CHMOIST2 + CHMOIST3
RUNOFF:
MAXSAT = FC * 1.15
RAIN = RAIN * 25.4 'CONVERTS RAIN FROM INCHES TO MILLIMETERS
S = (MAXSAT - CHMOIST) * RNC
IF RAIN = 0 THEN
  Q = 0
  GOTO RUNOFFEND
END IF
IF RAIN < .2 * S THEN
  Q = 0
  GOTO RUNOFFEND
END IF
IF CHMOIST > MAXSAT THEN
  Q = RAIN
  GOTO RUNOFFEND
END IF
IF RAIN > .2 * S THEN
  Q = (RAIN - (.2 * S)) ^ 2 / (RAIN + (.8 * S))
END IF
RUNOFFEND:
WATERINF = RAIN - Q
DRAINAGE:
RCHMOIST1 = CHMOIST1 + WATERINF
IF RCHMOIST1 < FCL THEN DRAIN1 = 0
IF RCHMOIST1 > FCL THEN
  DRAIN1 = (RCHMOIST1 - FCL) * DRN
END IF
DRNCHMOIST1 = RCHMOIST1 - DRAIN1
RCHMOIST2 = CHMOIST2 + DRAIN1
IF RCHMOIST2 < FCL THEN DRAIN2 = 0
IF RCHMOIST2 > FCL THEN
  DRAIN2 = (RCHMOIST2 - FCL) * DRN
END IF
DRNCHMOIST2 = RCHMOIST2 - DRAIN2
RCHMOIST3 = CHMOIST3 + DRAIN2
IF RCHMOIST3 < FCL THEN DRAIN3 = 0
IF RCHMOIST3 > FCL THEN
  DRAIN3 = (RCHMOIST3 - FCL) * DRN
END IF
DRNCHMOIST3 = RCHMOIST3 - DRAIN3
RCHMOIST4 = CHMOIST4 + DRAIN3
IF RCHMOIST4 < FCL THEN DRAIN4 = 0
IF RCHMOIST4 > FCL THEN
  DRAIN4 = (RCHMOIST4 - FCL) * DRN
END IF
DRNCHMOIST4 = RCHMOIST4 - DRAIN4
DIFFUSION12:
DIFF12 = ((DRNCHMOIST2 / FCL) - (DRNCHMOIST1 / FCL)) * FCL * DFF
IF DIFF12 = 0 THEN
  MOIST1 = DRNCHMOIST1
  MOIST2 = DRNCHMOIST2
END IF

```

```

IF DIFF12 > 0 THEN
  MOIST1 = DRNCHMOIST1 + DIFF12
  MOIST2 = DRNCHMOIST2 - DIFF12
  IF MOIST2 < WPL THEN
    DIFF12 = DRNCHMOIST2 - WPL
    MOIST1 = DRNCHMOIST1 + DIFF12
    MOIST2 = WPL
  END IF
END IF
IF DIFF12 < 0 THEN
  MOIST1 = DRNCHMOIST1 + DIFF12
  MOIST2 = DRNCHMOIST2 - DIFF12
  IF MOIST1 < WPL THEN
    DIFF12 = DRNCHMOIST1 - WPL
    MOIST1 = WPL
    MOIST2 = DRNCHMOIST2 + DIFF12
  END IF
END IF
DIFF23 = ((DRNCHMOIST3 / FCL) - (MOIST2 / FCL)) * FCL * DFF
IF DIFF23 = 0 THEN
  MOIST2 = MOIST2
  MOIST3 = DRNCHMOIST3
END IF
IF DIFF23 > 0 THEN
  MOIST2 = MOIST2 + DIFF23
  MOIST3 = DRNCHMOIST3 - DIFF23
  IF MOIST3 < WPL THEN
    DIFF23 = DRNCHMOIST3 - WPL
    MOIST2 = MOIST2 + DIFF23
    MOIST3 = WPL
  END IF
END IF
IF DIFF23 < 0 THEN
  MOIST2 = MOIST2 + DIFF23
  MOIST3 = DRNCHMOIST3 - DIFF23
  IF MOIST2 < WPL THEN
    DIFF23 = MOIST2 - WPL
    MOIST2 = WPL
    MOIST3 = DRNCHMOIST3 + DIFF23
  END IF
END IF
DIFF34 = ((DRNCHMOIST4 / FCL) - (MOIST3 / FCL)) * FCL * DFF
IF DIFF34 = 0 THEN
  MOIST3 = MOIST3
  MOIST4 = DRNCHMOIST4
END IF
IF DIFF34 > 0 THEN
  MOIST3 = MOIST3 + DIFF34
  MOIST4 = DRNCHMOIST4 - DIFF34
  IF MOIST4 < WPL THEN
    DIFF23 = DRNCHMOIST4 - WPL
    MOIST3 = MOIST3 + DIFF34
    MOIST4 = WPL
  END IF
END IF
IF DIFF34 < 0 THEN
  MOIST3 = MOIST3 + DIFF34
  MOIST4 = DRNCHMOIST4 - DIFF34
  IF MOIST3 < WPL THEN
    DIFF34 = DRNCHMOIST2 - WPL
    MOIST3 = WPL
    MOIST4 = DRNCHMOIST4 + DIFF34
  END IF
END IF

/ ***** DEFINES THE FIELD OPERATIONS BY MONTH AND CROP *****

IF OPERMONTH1 = 1 THEN
  IF MONTH = 1 THEN OPERMONTH = 1
END IF
IF OPERMONTH1 = 2 THEN
  IF MONTH = 1 THEN OPERMONTH = 2
END IF
IF OPERMONTH2 = 1 THEN
  IF MONTH = 2 THEN OPERMONTH = 1
END IF
IF OPERMONTH2 = 2 THEN
  IF MONTH = 2 THEN OPERMONTH = 2

```

```

END IF
IF OPERMONTH3 = 1 THEN
  IF MONTH = 3 THEN OPERMONTH = 1
END IF
IF OPERMONTH3 = 2 THEN
  IF MONTH = 3 THEN OPERMONTH = 2
END IF
IF OPERMONTH4 = 1 THEN
  IF MONTH = 4 THEN OPERMONTH = 1
END IF
IF OPERMONTH4 = 2 THEN
  IF MONTH = 4 THEN OPERMONTH = 2
END IF
IF OPERMONTH5 = 1 THEN
  IF MONTH = 5 THEN OPERMONTH = 1
END IF
IF OPERMONTH5 = 2 THEN
  IF MONTH = 5 THEN OPERMONTH = 2
END IF
IF OPERMONTH6 = 1 THEN
  IF MONTH = 6 THEN OPERMONTH = 1
END IF
IF OPERMONTH6 = 2 THEN
  IF MONTH = 6 THEN OPERMONTH = 2
END IF
IF OPERMONTH7 = 1 THEN
  IF MONTH = 7 THEN OPERMONTH = 1
END IF
IF OPERMONTH7 = 2 THEN
  IF MONTH = 7 THEN OPERMONTH = 2
END IF
IF OPERMONTH8 = 1 THEN
  IF MONTH = 8 THEN OPERMONTH = 1
END IF
IF OPERMONTH8 = 2 THEN
  IF MONTH = 8 THEN OPERMONTH = 2
END IF
IF OPERMONTH9 = 1 THEN
  IF MONTH = 9 THEN OPERMONTH = 1
END IF
IF OPERMONTH9 = 2 THEN
  IF MONTH = 9 THEN OPERMONTH = 2
END IF
IF OPERMONTH10 = 1 THEN
  IF MONTH = 10 THEN OPERMONTH = 1
END IF
IF OPERMONTH10 = 2 THEN
  IF MONTH = 10 THEN OPERMONTH = 2
END IF

IF OPERMONTH11 = 1 THEN
  IF MONTH = 11 THEN OPERMONTH = 1
END IF
IF OPERMONTH11 = 2 THEN
  IF MONTH = 11 THEN OPERMONTH = 2
END IF
IF OPERMONTH12 = 1 THEN
  IF MONTH = 12 THEN OPERMONTH = 1
END IF
IF OPERMONTH12 = 2 THEN
  IF MONTH = 12 THEN OPERMONTH = 2
END IF
IF MONTH = 12 THEN
  IF N = 31 THEN
    YEARCOUNT = YEARCOUNT + 1
  END IF
END IF

```

***** STARTS TO DEFINE IF THE DAY N IS OR NOT A WORKING DAY *****

DECISION:

```

WT1 = (FCL1 * T1) / 100
WT2 = (FCL2 * T2) / 100
WT3 = (FCL3 * T3) / 100
WTN1 = (FCL1 * TN1) / 100
WTN2 = (FCL2 * TN2) / 100
WTN3 = (FCL3 * TN3) / 100
IF MOIST1 < WT1 THEN ZONET1 = 1

```

```

IF MOIST2 < WT2 THEN ZONET2 = 1
IF MOIST3 < WT3 THEN ZONET3 = 1
IF MOIST1 > WT1 THEN ZONET1 = 0
IF MOIST2 > WT2 THEN ZONET2 = 0
IF MOIST3 > WT3 THEN ZONET3 = 0
TOTZONET = ZONET1 + ZONET2 + ZONET3
IF TOTZONET < 3 THEN WTV = 0
IF TOTZONET = 3 THEN WTV = 1
IF MOIST1 < WTN1 THEN ZONETN1 = 1
IF MOIST2 < WTN2 THEN ZONETN2 = 1
IF MOIST3 < WTN3 THEN ZONETN3 = 1
IF MOIST1 > WTN1 THEN ZONETN1 = 0
IF MOIST2 > WTN2 THEN ZONETN2 = 0
IF MOIST3 > WTN3 THEN ZONETN3 = 0
TOTZONETN = ZONETN1 + ZONETN2 + ZONETN3
IF TOTZONETN < 3 THEN WTNV = 0
IF TOTZONETN = 3 THEN WTNV = 1
PWDI = PWDI + WTV
PWDNT = PWDNT + WTNV
TILL = TILL + WTV
NTILL = NTILL + WTNV

***** STARTS PRINT OUTPUT FOR DAILY OPTIONS *****

IF OUTF = 1 THEN
  IF CROP = 1 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "###"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; DIFF12; SPC(1); DIFF23; SPC(1); DIFF34; SPC(1) MOIST1; SPC(1); MOIST2;
      SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); : PRINT #1, WTV; SPC(2); "-"
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "###"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; DIFF12; SPC(1); DIFF23; SPC(1); DIFF34; SPC(1) MOIST1; SPC(1); MOIST2;
      SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); : PRINT #1, "-"; SPC(2); WTNV
    END IF
  END IF
  IF CROP = 2 THEN
    IF OPERMONTH = 1 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "###"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; DIFF12; SPC(1); DIFF23; SPC(1); DIFF34; SPC(1) MOIST1; SPC(1); MOIST2;
      SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); : PRINT #1, "-"; SPC(2); WTNV
    END IF
    IF OPERMONTH = 2 THEN
      PRINT #1, USING "###"; SPC(1); MONTH; SPC(1); N; SPC(2); : PRINT #1, USING "###.##"; PET;
      SPC(1); ET1; SPC(1); ET2; SPC(1); ET3; SPC(1); : PRINT #1, USING "###"; RAIN; SPC(1);
      Q; SPC(1); : PRINT #1, USING "###.##"; DRAIN1; SPC(1); DRAIN2; SPC(1);
      DRAIN3; DIFF12; SPC(1); DIFF23; SPC(1); DIFF34; SPC(1) MOIST1; SPC(1); MOIST2;
      SPC(1); MOIST3; SPC(1); TOTMOIST; SPC(2); : PRINT #1, "-"; SPC(2); "-"
    END IF
  END IF
END IF
IMOIST1 = MOIST1
IMOIST2 = MOIST2
IMOIST3 = MOIST3
IMOIST4 = MOIST4
LOOP

```

APPENDIX C

APPENDIX C: Examples of documents used to collect field operations observed data.

1. "Informe de Servicio de Maquinaria Agricola" - South Coast Vegetable Program (SCVP).
2. "Resumen de uso de horas de operadores" - Agricultural Services Administration (ASA).

1. "Informe de Servicio de Maquinaria Agricola" - South Coast Vegetable Program.

This document is used by the SCVP to charge the farmers in the program the machinery service cost. The document includes the farm location, type of operation performed as plowing, disking, furrowing, harvesting, chemicals aspersion, etc. Is also included the cost of each operation and the total cost for the week.

№ 2506

[illegible]

0010.00 0010.0000
0010.00 0010.0000
0010.00 0010.0000

Figure C.1. Example of the "Informe de Servicio de Maquinaria Agricola" - South Coast Vegetable Program.

2. "Resumen de uso de horas de operadores" - Agricultural Services Administration (ASA).

ASA's tractors operators need to fill out this document. This document includes the farm location, productive hours, lost-time due to maintenance, weather conditions (rainfall), repairment, and others.



CENTRO DE MAQUINARIA DE GUANICA

RESUMEN DE USO DE HORAS
DE OPERADORES

OPERADOR _____

MAQUINA NUM. _____

SEMANA TERMINADA: _____

DIA	HORAS PRODUCTIVAS	ESPERANDO REP. MEC.	ESPERANDO MANT.	ESPERANDO TRASLADO	LLUVIA	VAC. RES.	VAC. ENF.		TOTAL DEL DIA
LUNES									
MARTES									
MIÉRCOLES									
JUEVES									
VIERNES									
SABADO									
DOMINGO									
TOTAL DE LA SEMANA								TOTAL TRABAJADO	

J. T. C. - Ocasional de campo computacional.

Observaciones de otros roles, servicios en el curso de los días.

REEMBOLSO DE GASTOS DE VIAJES Y DIETAS

DIA	ENTRADA	SALIDA	LUGAR SALIDA	SITIO DE TRABAJO	DIETAS		VIAJE	TOTAL
					DES.	ALIM.		
LUN.								
MAR.								
MIÉ.								
JUE.								
VIÉ.								
SAB.								
DOM.								
TOTAL DE LA SEMANA:								

TIEMPO DE INFORME: _____

CERTIFICADO CORRECTO.

OBSERVACIONES: _____

FIRMA OPERADOR _____

FIRMA ADMINISTRADOR DEL CENTRO _____

Figure C.2. Example of the "Resumen de uso de horas de operadores" - Agricultural Services Administration

APPENDIX D

APPENDIX D: Field operations rough data.

The following tables (Tables D.1 to D..7) show all the observed field operations data for the south coast of Puerto Rico collected during summer of 1992. This data was used to validate the modified models. The definition of working and non-working days for the observed data is also presented.

Table D.1. Observed tillage operations data and definition of working days for the Santa Isabel Valley vegetable field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

	MEAN	REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)
SEPTEMBER TO MAY (ON-SEASON)		
NUMBER OF REPORTED DAYS [‡] = 91		
TOTAL HOURS = 3025	33 h/day	11 h/day
TOTAL OPERATIONS (op.) = 842	9 op./day	3 op./day
JUNE TO AUGUST (OFF-SEASON)		
NUMBER OF REPORTED DAYS [‡] = 152		
TOTAL HOURS = 3858	25 h/day	8 h/day
TOTAL OPERATIONS = 1095	7 op./day	2 op./day

DATE			DAY OF THE WEEK [‡]	PREC.	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY		(mm)	h/day	op./day	h/day ¹	op./day ⁵	W,NW [†]
1989									
	7	1	7	0.0					
	7	2	1	0.0					
	7	3	2	0.0	44	15	1	1	1
	7	4	hol**	0.0					
	7	5	4	10.7	7	2	0	1	0
	7	6	5	7.1	27	12	1	1	1
	7	7	6	0.0	20	5	1	1	1
	7	8	7	0.0					
	7	9	1	0.8					
	7	10	2	0.0	42	15	1	1	1
	7	11	3	0.0	28	9	1	1	1
	7	12	4	1.5	30	9	1	1	1
	7	13	5	1.3	24	7	1	1	1
	7	14	6	0.0	13	3	1	1	1
	7	15	7	0.0					

‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.

\$ - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.

† - Working or non working day base on number of hours per day (1 or 0 respectively).

§ - Working or non working day base on number of operations per day (1 or 0 respectively).

† - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).

* - The observed day was not considered as observed data.

** - Holiday

Table D.1. (cont'd).

7	16	1	0.0					
7	17	hol	0.0					
7	18	3	0.0	29	11	1	1	1
7	19	4	0.0	36	11	1	1	1
7	20	5	0.0	23	6	1	1	1
7	21	6	0.0	19	7	1	1	1
7	22	7	0.0					
7	23	1	7.1					
7	24	2	0.0	29	10	1	1	1
7	25	hol	1.8					
7	26	4	0.0	29	8	1	1	1
7	27	hol	0.0					
7	28	6	0.0	12	3	1	1	1
7	29	7	0.0					
7	30	1	0.0					
7	31	2	0.0	41	10	1	1	1
8	1	3	0.0	44	12	1	1	1
8	2	4	0.0	33	8	1	1	1
8	3	5	9.1	1	1	0	0	0
8	4	6	0.0	10	3	1	1	1
8	5	7	0.0					
8	6	1	9.7					
8	7	2	0.0	37	9	1	1	1
8	8	3	3.0	24	7	1	1	1
8	9	4	0.0	40	11	1	1	1
8	10	5	0.0	35	10	1	1	1
8	11	6	14.0	42	13	1	1	1
8	12	7	16.5					
8	13	1	0.0					
8	14	2	0.0	11	4	1	1	1
8	15	3	0.0	42	9	1	1	1
8	16	4	0.0	34	11	1	1	1
8	17	5	0.8	29	13	1	1	1
8	18	6	6.3	34	13	1	1	1
8	19	7	10.2					
8	20	1	1.3					
8	21	2	1.5	38	8	1	1	1
8	22	3	12.2	0	0	0	0	0
8	23	4	0.0	18	8	1	1	1
8	24	5	19.3	6	1	0	0	0
8	25	6	14.7	15	5	1	1	1
8	26	7	7.9					
8	27	1	0.0					
8	28	2	0.0	0	0	0	0	0
8	29	3	12.7	0	0	0	0	0
8	30	4	8.4	0	0	0	0	0
8	31	5	0.0	0	0	0	0	0
9	1	hol	0.0					
9	2	7	0.0					
9	3	1	1.3					
9	4	2	0.0	23	7	1	1	1
9	5	3	0.0	50	20	1	1	1
9	6	4	0.0	58	21	1	1	1
9	7	5	0.0	46	14	1	1	1
9	8	6	0.0	71	19	1	1	1
9	9	7	0.0					
9	10	1	0.0					
9	11	2	31.5	0	0	0	0	0

Table D.1. (cont'd).

1990	9	12	3	0.0	34	9	1	1	1
	9	13	4	0.0	44	13	1	1	1
	9	14	5	0.0	39	11	1	1	1
	9	15	6	3.8	33	11	1	1	1
	9	16	7	0.0					
	9	17	1	0.0					
	9	18	2	8.4	0	0	0	0	0
	9	19	3	9.7	0	0	0	0	0
	9	20	4	0.0	42	13	1	1	1
	9	21	5	8.6	29	12	1	1	1
	9	22	6	35.8	14	7	1	1	1
	9	23	7	52.6					
	9	24	1	29.2					
	9	25	2	0.0	0	0	0	0	0
	9	26	3	0.0	10	4	0	1	0
	9	27	4	0.0	70	21	1	1	1
	9	28	5	0.0	41	10	1	1	1
	9	29	6	1.8	57	13	1	1	1
	9	30	7	0.0					
	5	1	3	0.0	15	4	1	1	1
	5	2	4	1.3	21	5	1	1	1
	5	3	5	0.5	26	5	1	1	1
	5	4	6	0.0	21	6	1	1	1
	5	5	7	0.0					
	5	6	1	0.0					
	5	7	2	0.0	17	4	1	1	1
	5	8	3	0.0	16	5	1	1	1
	5	9	4	0.0	18	6	1	1	1
	5	10	5	0.0	20	6	1	1	1
	5	11	6	0.0	31	6	1	1	1
	5	12	7	0.0					
	5	13	1	0.0					
	5	14	2	0.0	29	7	1	1	1
	5	15	3	0.0	38	11	1	1	1
	5	16	4	0.0	35	11	1	1	1
	5	17	5	0.0	39	10	1	1	1
	5	18	6	0.0	21	6	1	1	1
	5	19	7	0.0					
	5	20	1	0.0					
	5	21	2	0.0	28	9	1	1	1
	5	22	3	0.0	22	5	1	1	1
	5	23	4	0.0	39	9	1	1	1
	5	24	5	0.0	30	8	1	1	1
	5	25	6	0.0	25	7	1	1	1
	5	26	7	0.0					
	5	27	1	0.0					
	5	28	hol	0.0					
	5	29	3	0.0	22	9	1	1	1
	5	30	4	0.0	39	10	1	1	1
	5	31	5	0.0	50	11	1	1	1
1990	6	1	6	0.0	33	8	1	1	1
	6	2	7	0.0					
	6	3	1	0.0					
	6	4	2	0.0	24	7	1	1	1
	6	5	3	0.0	31	9	1	1	1
	6	6	4	0.0	37	10	1	1	1
	6	7	5	0.0	42	11	1	1	1
	6	8	6	0.0	35	12	1	1	1

Table D.1. (cont'd).

6	9	7	0.0					
6	10	1	1.3					
6	11	2	0.0	5	3			*
6	12	3	0.0	14	3	1	1	1
6	13	4	0.0	14	4	1	1	1
6	14	5	16.0	15	5	1	1	1
6	15	6	26.2	0	0	0	0	0
6	16	7	5.8					
6	17	1	0.0					
6	18	2	0.0	0	0	0	0	0
6	19	3	16.0	0	0	0	0	0
6	20	4	0.8	3	1	0	0	0
6	21	5	0.0	2	1	0	0	0
6	22	6	0.0	33	11	1	1	1
6	23	7	2.5					
6	24	1	4.1					
6	25	2	0.0	19	7	1	1	1
6	26	3	0.0	33	10	1	1	1
6	27	4	0.0	36	10	1	1	1
6	28	5	0.0	28	11	1	1	1
6	29	6	0.0	28	9	1	1	1
6	30	7	0.0					
7	1	1	0.0					
7	2	2	0.0	33	8	1	1	1
7	3	3	0.0	40	9	1	1	1
7	4	hol	0.0					
7	5	5	0.0	32	8	1	1	1
7	6	6	1.5	7	2			*
7	7	7	0.0					
7	8	1	0.0					
7	9	2	0.0	34	11	1	1	1
7	10	3	0.0	35	9	1	1	1
7	11	4	0.0	17	7	1	1	1
7	12	5	0.0	11	4	1	1	1
7	13	6	0.0	0	0			*
7	14	7	0.0					
7	15	1	10.4					
7	16	2	19.6	2	1	0	0	0
7	17	hol	4.1					
7	18	4	6.6	4	2	0	1	0
7	19	5	3.6	17	5	1	1	1
7	20	6	0.0	26	6	1	1	1
7	21	7	0.0					
7	22	1	0.0					
7	23	2	0.0	22	9	1	1	1
7	24	3	0.8	19	6	1	1	1
7	25	hol	0.0					
7	26	5	3.8	7	2	0	1	0
7	27	6	14.7	0	0	0	0	0
7	28	7	0.0					
7	29	1	0.0					
7	30	2	0.3	16	4	1	1	1
7	31	3	0.0	18	6	1	1	1
8	1	4	0.0	18	6	1	1	1
8	2	5	0.0	29	10	1	1	1
8	3	6	3.3	6	2	0	1	0
8	4	7	7.6					
8	5	1	20.1					

Table D.1. (cont'd).

8	6	2	0.0	23	6	1	1	1
8	7	3	0.0	23	9	1	1	1
8	8	4	1.8	19	7	1	1	1
8	9	5	0.0	31	8	1	1	1
8	10	6	2.0	32	8	1	1	1
8	11	7	10.9					
8	12	1	0.0					
8	13	2	0.8	46	12	1	1	1
8	14	3	0.0	48	12	1	1	1
8	15	4	0.0	47	14	1	1	1
8	16	5	0.0	59	12	1	1	1
8	17	6	0.0	42	10	1	1	1
8	18	7	0.0					
8	19	1	0.0					
8	20	2	2.0	50	12	1	1	1
8	21	3	0.0	59	14	1	1	1
8	22	4	0.0	49	14	1	1	1
8	23	5	2.5	56	15	1	1	1
8	24	6	0.0	54	14	1	1	1
8	25	7	0.0					
8	26	1	0.0					
8	27	2	0.0	37	9	1	1	1
8	28	3	0.0	32	11	1	1	1
8	29	4	7.9	53	13	1	1	1
8	30	5	0.0	34	11	1	1	1
8	31	6	0.0	45	12	1	1	1
9	1	7	0.0					
9	2	1	7.6					
9	3	hol	3.3					
9	4	3	4.8	23	4	1	1	1
9	5	4	0.0	40	10	1	1	1
9	6	5	10.2	37	13	1	1	1
9	7	6	0.0	39	12	1	1	1
9	8	7	0.0					
9	9	1	0.0					
9	10	2	2.3	40	11	1	1	1
9	11	3	0.0	46	12	1	1	1
9	12	4	0.0	55	12	1	1	1
9	13	5	0.3	52	11	1	1	1
9	14	6	0.3	44	10	1	1	1
9	15	7	18.8					
9	16	1	6.3					
9	17	2	0.0	11	3	1	1	1
9	18	3	0.0	37	10	1	1	1
9	19	4	0.0	50	14	1	1	1
9	20	5	0.0	57	13	1	1	1
9	21	6	0.0	43	12	1	1	1
9	22	7	0.0					
9	23	1	3.0					
9	24	2	0.0	25	7	1	1	1
9	25	3	4.3	31	6	1	1	1
9	26	4	0.5	25	7	1	1	1
9	27	5	10.7	35	8	1	1	1
9	28	6	9.4	12	3	1	1	1
9	29	7	13.5					
9	30	1	3.8					
1991								
5	1	4	0.0	42	14	1	1	1

Table D.1. (cont'd).

5	2	5	0.0	44	12	1	1	1
5	3	6	0.0	23	8	1	1	1
5	4	7	0.0					
5	5	1	0.0					
5	6	2	0.0	34	8	1	1	1
5	7	3	0.8	30	7	1	1	1
5	8	4	5.3	38	9	1	1	1
5	9	5	0.0	31	7	1	1	1
5	10	6	0.0	15	4	1	1	1
5	11	7	0.0					
5	12	1	0.5					
5	13	2	0.0	26	7	1	1	1
5	14	3	0.0	0	0			*
5	15	4	0.0	16	4	1	1	1
5	16	5	0.0	30	10	1	1	1
5	17	6	0.0	31	7	1	1	1
5	18	7	5.3					
5	19	1	2.3					
5	20	2	0.0	24	8	1	1	1
5	21	3	0.0	30	10	1	1	1
5	22	4	24.4	0	0	0	0	0
5	23	5	0.0	17	3	1	1	1
5	24	6	0.0	20	7	1	1	1
5	25	7	7.4					
5	26	1	1.5					
5	27	hol	0.0					
5	28	3	0.0	38	11	1	1	1
5	29	4	0.0	19	6	1	1	1
5	30	5	0.0	24	9	1	1	1
5	31	6	0.0	16	4	1	1	1
6	1	7	0.0					
6	2	1	0.0					
6	3	2	1.8	30	5	1	1	1
6	4	3	0.0	29	7	1	1	1
6	5	4	1.3	29	6	1	1	1
6	6	5	11.9	30	7	1	1	1
6	7	6	2.0	33	7	1	1	1
6	8	7	0.0					
6	9	1	0.0					
6	10	2	0.0	23	4	1	1	1
6	11	3	6.9	25	5	1	1	1
6	12	4	9.7	0	0	0	0	0
6	13	5	3.3	22	7	1	1	1
6	14	6	0.0	34	10	1	1	1
6	15	7	0.0					
6	16	1	0.0					
6	17	2	0.0	36	8	1	1	1
6	18	3	0.0	28	9	1	1	1
6	19	4	0.0	25	7	1	1	1
6	20	5	1.8	14	5	1	1	1
6	21	6	0.8	13	3	1	1	1
6	22	7	0.0					
6	23	1	0.0					
6	24	2	0.0	29	9	1	1	1
6	25	3	0.0	29	9	1	1	1
6	26	4	0.0	23	8	1	1	1
6	27	5	0.0	31	5	1	1	1

Table D.1. (cont'd).

6	28	6	0.0	28	7	1	1	1
6	29	7	0.0					
6	30	1	0.0					
7	1	2	2.5	17	5	1	1	1
7	2	3	0.0	7	3			*
7	3	4	0.0	22	6	1	1	1
7	4	hol	0.0					
7	5	6	0.0	11	4	1	1	1
7	6	7	0.0					
7	7	1	0.0					
7	8	2	1.5	12	4	1	1	1
7	9	3	0.0	14	3	1	1	1
7	10	4	0.0	13	4	1	1	1
7	11	5	0.0	3	1			*
7	12	6	0.0	7	3			*
7	13	7	0.0					
7	14	1	0.0					
7	15	2	0.0	11	3	1	1	1
7	16	3	63.5	0	0	0	0	0
7	17	hol	32.8					
7	18	5	0.0	5	1	0	0	0
7	19	6	8.9	13	3	1	1	1
7	20	7	0.0					
7	21	1	0.0					
7	22	2	0.0	20	5	1	1	1
7	23	3	0.0	26	6	1	1	1
7	24	4	0.0	22	6	1	1	1
7	25	hol	0.0					
7	26	6	0.0	24	8	1	1	1
7	27	7	0.0					
7	28	1	0.0					
7	29	2	0.0	20	8	1	1	1
7	30	3	0.0	9	1			*
7	31	4	0.0	23	6	1	1	1
8	1	5	0.0	13	4	1	1	1
8	2	6	0.0	27	10	1	1	1
8	3	7	0.0					
8	4	1	0.0					
8	5	2	0.0	22	10	1	1	1
8	6	3	0.0	17	3	1	1	1
8	7	4	0.0	31	12	1	1	1
8	8	5	0.0	18	4	1	1	1
8	9	6	0.0	7	1			*
8	10	7	0.0					
8	11	1	0.0					
8	12	2	3.8	16	4	1	1	1
8	13	3	0.0	13	3	1	1	1
8	14	4	1.8	36	8	1	1	1
8	15	5	0.0	9	3	1	1	1
8	16	6	6.3	13	10	1	1	1
8	17	7	0.0					
8	18	1	0.0					
8	19	2	0.0	16	5	1	1	1
8	20	3	0.0	13	4	1	1	1
8	21	4	1.3	7	1			*
8	22	5	0.8	3	1	0	0	0

Table D.1. (cont'd).

8	23	6	47.8	0	0	0	0	0
8	24	7	0.0					
8	25	1	0.0					
8	26	2	4.1	41	7	1	1	1
8	27	3	4.6	56	12	1	1	1
8	28	4	0.5	42	9	1	1	1
8	29	5	0.0	33	9	1	1	1
8	30	6	3.8	28	6	1	1	1
8	31	7	0.0					
9	1	1	0.0					
9	2	hol	0.0					
9	3	3	0.0	45	10	1	1	1
9	4	4	0.0	49	14	1	1	1
9	5	5	0.0	33	9	1	1	1
9	6	6	0.0	36	15	1	1	1
9	7	7	0.0					
9	8	1	6.6					
9	9	2	0.0	49	15	1	1	1
9	10	3	1.5	43	13	1	1	1
9	11	4	0.0	36	11	1	1	1
9	12	5	0.0	47	13	1	1	1
9	13	6	0.0	47	14	1	1	1
9	14	7	0.0					
9	15	1	0.0					
9	16	2	13.0	36	8	1	1	1
9	17	3	8.4	0	0	0	0	0
9	18	4	13.0	0	0	0	0	0
9	19	5	0.0	0	0	0	0	0
9	20	6	0.0	0	0	0	0	0
9	21	7	0.0					
9	22	1	13.5					
9	23	2	5.3	0	0	0	0	0
9	24	3	0.3	0	0	0	0	0
9	25	4	0.0	19	5	1	1	1
9	26	5	0.0	21	5	1	1	1
9	27	6	0.0	12	3	1	1	1
9	28	7	0.3					
9	29	1	0.0					
9	30	2	0.5	39	9	1	1	1

Table D.2. Observed non-tillage operations data and definition of working days for the Santa Isabel Valley vegetable field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

				MEAN		REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)		
				SEPTEMBER TO MAY (ON-SEASON)				
NUMBER OF REPORTED DAYS [‡] =				354				
TOTAL HOURS =				6787		19 h/day		
TOTAL OPERATIONS (op.) =				2084		6 op./day		
						2 op./day		
DATE		DAY OF THE WEEK ^{\$}	PREC.	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY	(mm)	h/day	op./day	h/day [‡]	op./day [§]	W, NW [†]
1989								
	10	1	1	0.0				
	10	2	2	17.8	26	10	1	1
	10	3	3	0.0	21	12	1	1
	10	4	4	0.0	30	9	1	1
	10	5	5	0.0	22	7	1	1
	10	6	6	0.0	30	8	1	1
	10	7	7	0.0				
	10	8	1	0.0				
	10	9	2	0.3	8	5	1	1
	10	10	3	0.0	21	9	1	1
	10	11	4	0.0	23	11	1	1
	10	12	hol**	0.0				
	10	13	6	0.0	26	11	1	1
	10	14	7	0.0				
	10	15	1	0.0				
	10	16	2	0.0	12	7	1	1
	10	17	3	2.8	23	8	1	1
	10	18	4	0.0	24	8	1	1
	10	19	5	2.8	27	10	1	1
	10	20	6	1.5	15	6	1	1

- ‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.
^{\$} - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.
[‡] - Working or non working day base on number of hours per day (1 or 0 respectively).
[§] - Working or non working day base on number of operations per day (1 or 0 respectively).
[†] - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).
* - The observed day was not considered as observed data.
** - Holiday

Table D.2. (cont'd).

10	21	7	16.3					
10	22	1	0.5					
10	23	2	0.0	11	5	1	1	1
10	24	3	0.0	25	11	1	1	1
10	25	4	0.0	21	7	1	1	1
10	26	5	0.0	24	10	1	1	1
10	27	6	0.0	6	1			*
10	28	7	0.0					
10	29	1	2.5					
10	30	2	1.0	10	4	1	1	1
10	31	3	0.0	25	9	1	1	1
11	1	4	0.0	9	4	1	1	1
11	2	5	0.0	25	9	1	1	1
11	3	6	0.0	15	6	1	1	1
11	4	7	0.0					
11	5	1	0.0					
11	6	2	9.7	12	6	1	1	1
11	7	3	0.5	12	5	1	1	1
11	8	4	0.0	24	9	1	1	1
11	9	5	1.8	11	4	1	1	1
11	10	6	0.0	17	6	1	1	1
11	11	7	0.0					
11	12	1	0.0					
11	13	2	0.0	16	8	1	1	1
11	14	3	0.0	20	9	1	1	1
11	15	4	0.0	17	7	1	1	1
11	16	5	0.0	9	4	1	1	1
11	17	6	0.0	24	7	1	1	1
11	18	7	0.0					
11	19	1	0.0					
11	20	2	0.0	10	2	1	1	1
11	21	3	0.0	24	9	1	1	1
11	22	4	0.0	23	10	1	1	1
11	23	hol	0.0					
11	24	6	0.0	0	0			*
11	25	7	0.0					
11	26	1	0.0					
11	27	2	0.0	22	7	1	1	1
11	28	3	0.0	31	9	1	1	1
11	29	4	0.0	28	10	1	1	1
11	30	5	0.0	21	8	1	1	1
12	1	6	0.0	25	9	1	1	1
12	2	7	0.0					
12	3	1	0.0					
12	4	2	2.5	24	10	1	1	1
12	5	3	0.0	12	5	1	1	1
12	6	4	0.0	15	6	1	1	1
12	7	5	0.0	14	6	1	1	1
12	8	6	0.0	10	3	1	1	1
12	9	7	0.0					
12	10	1	0.0					
12	11	2	0.0	10	7	1	1	1
12	12	3	0.0	10	4	1	1	1
12	13	4	0.0	7	4	1	1	1
12	14	5	0.0	6	5	1	1	1
12	15	6	0.0	9	4	1	1	1
12	16	7	0.0					
12	17	1	0.0					

Table D.2. (cont'd).

1990	12	18	2	0.0	11	6	1	1	1	
	12	19	3	0.0	20	5	1	1	1	
	12	20	4	0.0	14	8	1	1	1	
	12	21	5	0.0	22	5	1	1	1	
	12	22	6	0.0	8	2	1	1	1	
	12	23	7	0.0						
	12	24	1	0.0						
	12	25	hol	0.0						
	12	26	3	0.0	9	4	1	1	1	
	12	27	4	0.0	25	9	1	1	1	
	12	28	5	0.0	11	7	1	1	1	
	12	29	6	0.0	12	3	1	1	1	
	12	30	7	5.6						
	12	31	1	0.0						
		1	1	hol	0.0					
		1	2	3	4.6	13	4	1	1	1
		1	3	4	0.0	19	9	1	1	1
		1	4	5	0.0	11	7	1	1	1
		1	5	6	0.0	7	3	1	1	1
		1	6	7	0.0					
		1	7	1	0.0					
		1	8	2	0.0	14	6	1	1	1
		1	9	3	0.0	16	7	1	1	1
		1	10	4	0.5	14	5	1	1	1
		1	11	hol	0.3					
		1	12	6	0.0	11	6	1	1	1
		1	13	7	1.8					
		1	14	1	0.0					
		1	15	hol	0.0					
		1	16	3	0.0	16	7	1	1	1
		1	17	4	0.0	8	2	1	1	1
		1	18	5	0.0	15	7	1	1	1
		1	19	6	0.0	12	7	1	1	1
		1	20	7	0.8					
		1	21	1	6.1					
		1	22	2	0.0	17	5	1	1	1
		1	23	3	0.0	13	4	1	1	1
		1	24	4	0.8	17	6	1	1	1
		1	25	5	0.0	21	10	1	1	1
		1	26	6	0.0	12	3	1	1	1
		1	27	7	0.0					
		1	28	1	1.0					
		1	29	2	0.0	9	4	1	1	1
		1	30	3	0.0	13	5	1	1	1
		1	31	4	0.0	15	6	1	1	1
		2	1	5	0.0	15	6	1	1	1
	2	2	6	0.0	8	6	1	1	1	
	2	3	7	0.0						
	2	4	1	0.0						
	2	5	2	0.0	22	6	1	1	1	
	2	6	3	0.0	21	5	1	1	1	
	2	7	4	0.0	24	7	1	1	1	
	2	8	5	0.3	35	11	1	1	1	
	2	9	6	0.0	32	8	1	1	1	
	2	10	7	1.8						
	2	11	1	0.0						
	2	12	2	0.0	31	8	1	1	1	
	2	13	3	1.8	25	8	1	1	1	

Table D.2. (cont'd).

2	14	4	0.8	12	4	1	1	1
2	15	5	0.0	15	5	1	1	1
2	16	6	0.0	14	4	1	1	1
2	17	7	0.0					
2	18	1	0.0					
2	19	hol	0.0					
2	20	3	0.0	8	4	1	1	1
2	21	4	1.0	8	4	1	1	1
2	22	5	0.0	9	3	1	1	1
2	23	6	0.3	17	6	1	1	1
2	24	7	0.3					
2	25	1	0.0					
2	26	2	0.0	9	7	1	1	1
2	27	3	0.0	23	7	1	1	1
2	28	4	0.0	19	6	1	1	1
3	1	5	0.0	14	5	1	1	1
3	2	6	3.6	11	3	1	1	1
3	3	7	0.0					
3	4	1	0.0					
3	5	2	0.0	26	9	1	1	1
3	6	3	0.0	17	4	1	1	1
3	7	4	0.0	22	7	1	1	1
3	8	5	0.0	32	10	1	1	1
3	9	6	0.0	17	3	1	1	1
3	10	7	0.0					
3	11	1	0.0					
3	12	2	1.3	37	11	1	1	1
3	13	3	0.0	22	6	1	1	1
3	14	4	1.3	29	7	1	1	1
3	15	5	0.0	38	14	1	1	1
3	16	6	0.0	22	5	1	1	1
3	17	7	0.0					
3	18	1	0.0					
3	19	2	0.0	21	7	1	1	1
3	20	3	0.0	21	8	1	1	1
3	21	4	0.0	10	5	1	1	1
3	22	hol	0.0					
3	23	6	0.0	23	5	1	1	1
3	24	7	0.0					
3	25	1	0.0					
3	26	2	0.0	19	7	1	1	1
3	27	3	0.0	8	4	1	1	1
3	28	4	0.0	18	5	1	1	1
3	29	5	0.3	21	7	1	1	1
3	30	6	0.0	17	7	1	1	1
3	31	7	0.0					
4	1	1	0.0					
4	2	2	6.6	22	8	1	1	1
4	3	3	0.3	11	5	1	1	1
4	4	4	0.0	23	8	1	1	1
4	5	5	0.0	19	7	1	1	1
4	6	6	0.0	9	4	1	1	1
4	7	7	0.0					
4	8	1	0.0					
4	9	2	0.0	13	7	1	1	1
4	10	3	0.0	18	6	1	1	1
4	11	4	0.0	23	7	1	1	1
4	12	hol	0.0					

Table D.2. (cont'd).

4	13	hol	0.0					
4	14	7	0.0					
4	15	1	1.0					
4	16	hol	0.0					
4	17	3	0.0	17	6	1	1	1
4	18	4	0.0	14	5	1	1	1
4	19	5	0.0	11	5	1	1	1
4	20	6	11.7	6	4	1	1	1
4	21	7	0.0					
4	22	1	0.0					
4	23	2	0.0	5	4			*
4	24	3	0.0	6	4	1	1	1
4	25	4	6.1	14	5	1	1	1
4	26	5	0.3	5	1	0	0	0
4	27	6	13.0	16	5	1	1	1
4	28	7	0.0					
4	29	1	0.0					
4	30	2	0.0	14	7	1	1	1
10	1	2	0.0	19	8	1	1	1
10	2	3	0.0	20	8	1	1	1
10	3	4	7.6	24	9	1	1	1
10	4	5	0.0	15	5	1	1	1
10	5	6	0.5	17	7	1	1	1
10	6	7	6.9					
10	7	1	3.8					
10	8	2	10.7	0	0	0	0	0
10	9	3	32.0	0	0	0	0	0
10	10	4	19.3	0	0	0	0	0
10	11	5	6.3	0	0	0	0	0
10	12	hol	24.9					
10	13	7	18.0					
10	14	1	19.8					
10	15	2	2.3	0	0	0	0	0
10	16	3	6.6	0	0	0	0	0
10	17	4	0.8	0	0	0	0	0
10	18	5	0.3	0	0	0	0	0
10	19	6	20.6	0	0	0	0	0
10	20	7	39.4					
10	21	1	54.4					
10	22	2	16.8	0	0	0	0	0
10	23	3	0.3	0	0	0	0	0
10	24	4	18.5	0	0	0	0	0
10	25	5	28.2	0	0	0	0	0
10	26	6	35.8	0	0	0	0	0
10	27	7	13.0					
10	28	1	14.2					
10	29	2	15.2	0	0	0	0	0
10	30	3	21.8	0	0	0	0	0
10	31	4	11.9	0	0	0	0	0
11	1	5	0.0	0	0	0	0	0
11	2	6	0.0	0	0	0	0	0
11	3	7	0.0					
11	4	1	0.0					
11	5	2	6.3	3	3	0	1	0
11	6	3	7.1	6	3	1	1	1
11	7	4	0.0	10	4	1	1	1
11	8	5	0.0	13	5	1	1	1
11	9	6	0.0	23	6	1	1	1

Table D.2. (cont'd).

11	10	7	0.0					
11	11	1	0.0					
11	12	hol	2.0					
11	13	4	0.0	8	3			*
11	14	4	0.0	5	2			*
11	15	5	0.0	39	9	1	1	1
11	16	6	0.0	22	7	1	1	1
11	17	7	0.0					
11	18	1	0.0					
11	19	hol	0.0					
11	20	3	0.0	20	9	1	1	1
11	21	4	1.0	12	5	1	1	1
11	22	hol	11.4					
11	23	6	0.0	14	3	1	1	1
11	24	7	0.0					
11	25	1	0.0					
11	26	2	0.0	17	4	1	1	1
11	27	3	0.0	18	9	1	1	1
11	28	4	0.0	20	5	1	1	1
11	29	5	0.0	16	6	1	1	1
11	30	6	0.5	12	3	1	1	1
12	1	7	10.4					
12	2	1	0.0					
12	3	2	0.0	10	4	1	1	1
12	4	3	0.0	21	7	1	1	1
12	5	4	0.0	28	10	1	1	1
12	6	5	0.0	33	7	1	1	1
12	7	6	0.0	46	8	1	1	1
12	8	7	0.0					
12	9	1	0.0					
12	10	2	0.0	35	12	1	1	1
12	11	3	0.0	47	11	1	1	1
12	12	4	0.0	29	7	1	1	1
12	13	5	0.0	26	8	1	1	1
12	14	6	2.8	22	6	1	1	1
12	15	7	0.0					
12	16	1	2.3					
12	17	2	0.0	41	10	1	1	1
12	18	3	0.0	32	7	1	1	1
12	19	4	0.0	32	7	1	1	1
12	20	5	0.0	28	5	1	1	1
12	21	6	0.0	38	10	1	1	1
12	22	7	0.0					
12	23	1	0.0					
12	24	2	0.0	0	0			*
12	25	hol	0.0					
12	26	4	0.0	22	4	1	1	1
12	27	5	0.5	25	6	1	1	1
12	28	6	0.0	11	4	1	1	1
12	29	7	0.5					
12	30	1	0.0					
12	31	2	0.3	0	0			*
1991	1	1	hol					
	1	2	4	19	5	1	1	1
	1	3	5	4	2			*
	1	4	6	19	6	1	1	1
	1	5	7					
	1	6	1					

Table D.2. (cont'd).

1	7	hol	0.0					
1	8	3	0.0	20	7	1	1	1
1	9	4	0.3	25	7	1	1	1
1	10	5	0.8	15	4	1	1	1
1	11	hol	0.3					
1	12	7	0.0					
1	13	1	0.0					
1	14	2	0.0	16	6	1	1	1
1	15	3	2.5	16	4	1	1	1
1	16	4	0.0	13	4	1	1	1
1	17	5	0.0	29	8	1	1	1
1	18	6	0.0	29	6	1	1	1
1	19	7	0.0					
1	20	1	0.0					
1	21	2	0.0	4	2			*
1	22	3	0.0	21	5	1	1	1
1	23	4	0.0	19	6	1	1	1
1	24	5	0.0	21	6	1	1	1
1	25	6	0.0	19	4	1	1	1
1	26	7	0.0					
1	27	1	0.0					
1	28	2	0.8	23	7	1	1	1
1	29	3	0.0	19	6	1	1	1
1	30	4	0.5	37	7	1	1	1
1	31	5	0.0	18	7	1	1	1
2	1	6	0.3	32	9	1	1	1
2	2	7	0.0					
2	3	1	0.5					
2	4	2	0.0	23	5	1	1	1
2	5	3	4.1	18	9	1	1	1
2	6	4	3.3	18	4	1	1	1
2	7	5	0.8	44	11	1	1	1
2	8	6	0.0	53	11	1	1	1
2	9	7	0.0					
2	10	1	2.5					
2	11	2	0.5	40	11	1	1	1
2	12	3	0.0	34	9	1	1	1
2	13	4	4.3	24	5	1	1	1
2	14	5	1.3	9	3	1	1	1
2	15	6	5.6	24	8	1	1	1
2	16	7	0.5					
2	17	1	3.0					
2	18	hol	2.0					
2	19	3	3.6	51	11	1	1	1
2	20	4	0.0	46	9	1	1	1
2	21	5	0.0	24	5	1	1	1
2	22	6	0.0	38	12	1	1	1
2	23	7	0.0					
2	24	1	0.0					
2	25	2	2.5	40	8	1	1	1
2	26	3	0.0	39	10	1	1	1
2	27	4	0.0	44	10	1	1	1
2	28	5	0.0	11	5	1	1	1
3	1	6	1.5	34	11	1	1	1
3	2	7	0.0					
3	3	1	0.0					
3	4	2	3.6	42	10	1	1	1
3	5	3	5.1	49	10	1	1	1

Table D.2. (cont'd).

3	6	4	6.1	28	8	1	1	1
3	7	5	1.3	31	11	1	1	1
3	8	6	1.0	23	8	1	1	1
3	9	7	0.8					
3	10	1	0.0					
3	11	2	0.0	5	1			*
3	12	3	0.0	9	3	1	1	1
3	13	4	0.0	8	3	1	1	1
3	14	5	0.0	18	4	1	1	1
3	15	6	0.0	14	5	1	1	1
3	16	7	0.0					
3	17	1	0.0					
3	18	2	0.0	14	5	1	1	1
3	19	3	0.0	16	7	1	1	1
3	20	4	0.0	25	7	1	1	1
3	21	5	0.0	17	5	1	1	1
3	22	hol	3.3					
3	23	7	2.3					
3	24	1	0.0					
3	25	2	0.0	6	1	1	0	0
3	26	3	13.5	20	6	1	1	1
3	27	4	24.9	6	1	1	0	0
3	28	hol	0.0					
3	29	hol	0.0					
3	30	7	0.0					
3	31	1	0.0					
4	1	2	0.0	8	1			*
4	2	3	0.0	7	2	1	1	1
4	3	4	2.8	9	3	1	1	1
4	4	5	0.0	8	4	1	1	1
4	5	6	0.0	2	2			*
4	6	7	4.8					
4	7	1	0.3					
4	8	2	0.0	8	2	1	1	1
4	9	3	1.0	9	5	1	1	1
4	10	4	0.0	15	4	1	1	1
4	11	5	0.0	18	5	1	1	1
4	12	6	0.0	9	5	1	1	1
4	13	7	0.0					
4	14	1	0.0					
4	15	2	0.0	4	2			*
4	16	hol	0.0					
4	17	4	0.3	9	5	1	1	1
4	18	5	0.0	9	3	1	1	1
4	19	6	0.0	6	4	1	1	1
4	20	7	0.0					
4	21	1	0.0					
4	22	2	0.3	4	2			*
4	23	3	0.0	0	0			*
4	24	4	0.0	24	7	1	1	1
4	25	5	0.0	13	3	1	1	1
4	26	6	0.0	16	8	1	1	1
4	27	7	0.0					
4	28	1	0.0					
4	29	2	0.0	3	1			*
4	30	3	0.0	4	2			*
10	1	3	0.0	2	1			*
10	2	4	0.0	5	1			*

Table D.2. (cont'd).

10	3	5	0.0	11	2	1	1	1
10	4	6	0.0	9	2	1	1	1
10	5	7	0.0					
10	6	1	8.1					
10	7	2	0.0	8	4	1	1	1
10	8	3	0.3	22	5	1	1	1
10	9	4	0.0	12	5	1	1	1
10	10	5	6.3	4	2	0	1	0
10	11	6	6.3	3	2	0	1	0
10	12	hol	2.5					
10	13	1	0.0					
10	14	2	0.0	12	3	1	1	1
10	15	3	0.0	5	1			*
10	16	4	0.8	10	4	1	1	1
10	17	5	2.3	5	1			*
10	18	6	0.0	29	3	1	1	1
10	19	7	0.0					
10	20	1	0.0					
10	21	2	0.0	12	4	1	1	1
10	22	3	0.0	15	4	1	1	1
10	23	4	8.1	10	4	1	1	1
10	24	5	0.0	20	5	1	1	1
10	25	6	0.0	12	3	1	1	1
10	26	7	0.0					
10	27	1	0.0					
10	28	2	0.0	16	4	1	1	1
10	29	3	0.0	21	5	1	1	1
10	30	4	0.8	11	5	1	1	1
10	31	5	0.0	9	2	1	1	1
11	1	6	0.0	17	5	1	1	1
11	2	7	0.0					
11	3	1	0.0					
11	4	2	0.0	19	6	1	1	1
11	5	3	3.0	15	4	1	1	1
11	6	4	18.5	20	4	1	1	1
11	7	5	13.5	0	0	0	0	0
11	8	6	7.4	0	0	0	0	0
11	9	7	4.3					
11	10	1	3.3					
11	11	hol	0.0					
11	12	3	0.0	25	9	1	1	1
11	13	4	0.0	23	8	1	1	1
11	14	5	0.0	28	6	1	1	1
11	15	6	0.0	8	1			*
11	16	7	0.0					
11	17	1	5.3					
11	18	2	4.6	15	4	1	1	1
11	19	hol	0.0					
11	20	4	0.0	15	4	1	1	1
11	21	5	1.3	16	5	1	1	1
11	22	6	0.0	28	9	1	1	1
11	23	7	0.0					
11	24	1	0.8					
11	25	2	0.8	17	4	1	1	1
11	26	3	0.0	14	3	1	1	1
11	27	4	25.7	0	0	0	0	0
11	28	hol	2.5					
11	29	6	0.0	0	0	0	0	0
11	30	7	0.0					

Table D.2. (cont'd).

12	1	1	0.0					
12	2	2	0.3	16	3	1	1	1
12	3	3	3.3	21	5	1	1	1
12	4	4	1.3	35	9	1	1	1
12	5	5	0.0	30	8	1	1	1
12	6	6	0.0	18	5	1	1	1
12	7	7	0.0					
12	8	1	0.0					
12	9	2	0.0	15	4	1	1	1
12	10	3	0.0	21	7	1	1	1
12	11	4	0.0	14	4	1	1	1
12	12	5	0.0	13	4	1	1	1
12	13	6	0.0	22	5	1	1	1
12	14	7	0.0					
12	15	1	0.0					
12	16	2	0.0	17	6	1	1	1
12	17	3	0.0	27	9	1	1	1
12	18	4	0.0	16	5	1	1	1
12	19	5	0.0	13	4	1	1	1
12	20	6	0.0	7	2	1	1	1
12	21	7	0.0					
12	22	1	0.0					
12	23	2	0.0	35	9	1	1	1
12	24	3	0.3	25	10	1	1	1
12	25	hol	0.0					
12	26	5	0.0	41	10	1	1	1
12	27	6	0.0	27	8	1	1	1
12	28	7	0.0					
12	29	1	0.0					
12	30	2	0.5	18	5	1	1	1
12	31	3	0.5	4	2			*
1992								
	1	1	hol					
	1	2	5					
	1	3	6	4	3			*
	1	4	7	7	3	1	1	1
	1	5	1					
	1	6	hol					
	1	7	3					
	1	8	4	0	0	0	0	0
	1	9	5	4	1	0	0	0
	1	10	6	6	1	1	0	0
	1	11	7	10	3	1	1	1
	1	12	1					
	1	13	2					
	1	14	3	10	3	1	1	1
	1	15	4	3	3			*
	1	16	5	4	1			*
	1	17	6	30	6	1	1	1
	1	18	7	23	6	1	1	1
	1	19	1					
	1	20	hol					
	1	21	3					
	1	22	4	4	3			*
	1	23	5	12	5	1	1	1
	1	24	6	22	8	1	1	1
	1	25	7	29	8	1	1	1
	1	26	1					
	1	27	2					
	1	28	3	23	8	1	1	1
				25	8	1	1	1

Table D.2. (cont'd).

1	29	4	0.0	18	5	1	1	1
1	30	5	0.0	27	7	1	1	1
1	31	6	0.0	35	10	1	1	1
2	1	7	0.0					
2	2	1	0.0					
2	3	2	0.0	23	8	1	1	1
2	4	3	0.0	18	5	1	1	1
2	5	4	2.5	24	4	1	1	1
2	6	5	3.3	49	9	1	1	1
2	7	6	1.0	40	11	1	1	1
2	8	7	0.8					
2	9	1	1.3					
2	10	2	0.0	31	8	1	1	1
2	11	3	0.0	31	9	1	1	1
2	12	hol	0.0					
2	13	5	0.0	21	5	1	1	1
2	14	6	0.0	10	4	1	1	1
2	15	7	1.0					
2	16	1	0.0					
2	17	2	0.0	12	2	1	1	1
2	18	3	0.0	22	6	1	1	1
2	19	4	0.0	32	6	1	1	1
2	20	5	0.0	22	5	1	1	1
2	21	6	0.0	26	8	1	1	1
2	22	7	0.0					
2	23	1	0.0					
2	24	2	0.0	20	7	1	1	1
2	25	3	4.1	31	8	1	1	1
2	26	4	2.0	30	10	1	1	1
2	27	5	0.0	35	9	1	1	1
2	28	6	0.0	29	8	1	1	1
2	29	7	0.0					

Table D.3 Observed tillage operations data and definition of working days for the Guanica Valley vegetable field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

	MEAN	REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)
<u>SEPTEMBER TO MAY (ON-SEASON)</u>		
NUMBER OF REPORTED DAYS [‡] = 85		
TOTAL HOURS = 768	9 h/day	3 h/day
TOTAL OPERATIONS (op.) = 241	3 op./day	1 op./day
<u>JUNE TO AUGUST (OFF-SEASON)</u>		
NUMBER OF REPORTED DAYS [‡] = 143		
TOTAL HOURS = 1281	9 h/day	3 h/day
TOTAL OPERATIONS (op.) = 387	3 op./day	1 op./day

DATE			DAY OF THE WEEK [‡]	PREC.	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY		(mm)	h/day	op./day	h/day [†]	op./day [§]	W,NW [†]
1989									
	7	1	7	0.0					
	7	2	1	0.0					
	7	3	2	0.0	3	2	1	1	1
	7	4	hol**	1.3					
	7	5	4	0.0	9	4	1	1	1
	7	6	5	0.0	0	0			*
	7	7	6	0.0	5	1	1	1	1
	7	8	7	0.0					
	7	9	1	0.0					
	7	10	2	1.3	2	2			*
	7	11	3	0.0	3	2	1	1	1
	7	12	4	2.3	13	4	1	1	1
	7	13	5	0.0	7	3	1	1	1
	7	14	6	0.0	2	1			*

‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.

§ - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.

¶ - Working or non working day base on number of hours per day (1 or 0 respectively).

§ - Working or non working day base on number of operations per day (1 or 0 respectively).

† - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).

* - The observed day was not considered as observed data.

** - Holiday

Table D.3. (cont'd).

7	15	7	0.0					
7	16	1	0.0					
7	17	hol	0.0					
7	18	3	0.0	0	0			*
7	19	4	0.0	5	3	1	1	1
7	20	5	0.0	8	2	1	1	1
7	21	6	0.0	8	3	1	1	1
7	22	7	0.0					
7	23	1	0.0					
7	24	2	3.8	3	1	1	1	1
7	25	hol	0.0					
7	26	4	0.0	2	1			*
7	27	hol	0.0					
7	28	6	0.0	0	0			*
7	29	7	0.0					
7	30	1	2.5					
7	31	2	0.0	12	2	1	1	1
8	1	3	0.0	0	0			*
8	2	4	0.0	1	1			*
8	3	5	0.0	0	0			*
8	4	6	0.0	5	3	1	1	1
8	5	7	0.0					
8	6	1	0.0					
8	7	2	0.0	25	4	1	1	1
8	8	3	0.0	21	4	1	1	1
8	9	4	0.0	18	3	1	1	1
8	10	5	0.0	16	2	1	1	1
8	11	6	0.0	16	2	1	1	1
8	12	7	0.0					
8	13	1	0.0					
8	14	2	0.0	7	2	1	1	1
8	15	3	0.0	3	2	1	1	1
8	16	4	0.0	5	2	1	1	1
8	17	5	19.6	4	1	1	1	1
8	18	6	0.0	5	1	1	1	1
8	19	7	0.0					
8	20	1	17.5					
8	21	2	0.0	4	1	1	1	1
8	22	3	0.0	2	1	0	1	0
8	23	4	15.2	5	2	1	1	1
8	24	5	0.0	0	0	0	0	0
8	25	6	0.0	7	2	1	1	1
8	26	7	0.0					
8	27	1	0.0					
8	28	2	0.0	6	2	1	1	1
8	29	3	0.0	3	3	1	1	1
8	30	4	0.0	9	2	1	1	1
8	31	5	7.6	2	1	0	1	0
9	1	6	0.0					
9	2	7	5.1					
9	3	1	2.5					
9	4	2	2.5	0	0	0	0	0
9	5	3	0.0	20	7	1	1	1
9	6	4	2.0	7	4	1	1	1
9	7	5	0.0	5	2	1	1	1
9	8	6	0.0	4	1	1	1	1
9	9	7	29.2					
9	10	1	29.2					

Table D.3. (cont'd).

1990	9	11	2	0.0	0	0			*
	9	12	3	0.0	1	1	0	1	0
	9	13	4	0.0	11	4	1	1	1
	9	14	5	0.0	6	3	1	1	1
	9	15	6	0.0	4	1	1	1	1
	9	16	7	0.0					
	9	17	1	0.0					
	9	18	2	15.2	0	0	0	0	0
	9	19	3	15.2	0	0	0	0	0
	9	20	4	15.2	0	0	0	0	0
	9	21	5	8.9	0	0	0	0	0
	9	22	6	50.8	0	0	0	0	0
	9	23	7	26.7					
	9	24	1	8.9					
	9	25	2	0.0	0	0	0	0	0
	9	26	3	0.0	2	1	0	1	0
	9	27	4	0.0	1	1	0	1	0
	9	28	5	34.8	2	1	0	1	0
	9	29	6	0.0	0	0	0	0	0
	9	30	7	15.5					
1990	5	1	3	2.5	5	1	1	1	1
	5	2	4	11.9	0	0	0	0	0
	5	3	5	0.0	0	0	0	0	0
	5	4	6	0.0	7	2	1	1	1
	5	5	7	0.0					
	5	6	1	0.0					
	5	7	2	0.0	5	3	1	1	1
	5	8	3	0.0	8	2	1	1	1
	5	9	4	0.0	10	2	1	1	1
	5	10	5	0.0	8	2	1	1	1
	5	11	6	0.0	10	2	1	1	1
	5	12	7	0.0					
	5	13	1	0.0					
	5	14	2	0.0	13	4	1	1	1
	5	15	3	0.0	14	3	1	1	1
	5	16	4	0.0	2	1			*
	5	17	5	0.0	6	1	1	1	1
	5	18	6	0.0	3	2	1	1	1
	5	19	7	0.0					
	5	20	1	0.0					
	5	21	2	0.0	4	2	1	1	1
	5	22	3	0.0	6	3	1	1	1
	5	23	4	0.0	6	3	1	1	1
	5	24	5	0.0	5	1	1	1	1
	5	25	6	0.0	9	2	1	1	1
	5	26	7	0.0					
	5	27	1	0.0					
	5	28	hol	0.0					
	5	29	3	0.0	11	2	1	1	1
	5	30	4	0.0	0	0			*
	5	31	5	0.0	3	2	1	1	1
1990	6	1	6	0.0	9	2	1	1	1
	6	2	7	0.0					
	6	3	1	0.0					
	6	4	2	0.0	8	2	1	1	1
	6	5	3	0.0	2	1			*
	6	6	4	0.0	2	1			*
	6	7	5	1.8	6	1	1	1	1

Table D.3. (cont'd).

6	8	6	0.0	0	0			*
6	9	7	0.0					
6	10	1	0.0					
6	11	2	0.0	9	3	1	1	1
6	12	3	2.5	6	1	1	1	1
6	13	4	0.0	15	3	1	1	1
6	14	5	114.3	3	1	0	0	0
6	15	6	11.9	0	0	0	0	0
6	16	7	0.0					
6	17	1	0.0					
6	18	2	3.8	5	2	1	1	1
6	19	3	0.0	0	0	0	0	0
6	20	4	0.0	8	3	1	1	1
6	21	5	0.0	8	3	1	1	1
6	22	6	0.0	5	3	1	1	1
6	23	7	0.0					
6	24	1	0.0					
6	25	2	0.0	7	3	1	1	1
6	26	3	0.0	0	0			*
6	27	4	0.0	10	2	1	1	1
6	28	5	0.0	13	4	1	1	1
6	29	6	0.0	7	4	1	1	1
6	30	7	0.0					
7	1	1	0.0					
7	2	2	0.0	8	3	1	1	1
7	3	3	0.0	4	2	1	1	1
7	4	hol	0.0					
7	5	5	0.0	18	7	1	1	1
7	6	6	0.0	0	0			*
7	7	7	0.0					
7	8	1	0.0					
7	9	2	0.0	11	5	1	1	1
7	10	3	0.0	12	3	1	1	1
7	11	4	0.0	3	2	1	1	1
7	12	5	0.0	4	1	1	1	1
7	13	6	0.0	2	2			*
7	14	7	0.0					
7	15	1	76.2					
7	16	2	8.1	0	0	0	0	0
7	17	hol	3.8					
7	18	4	0.0	0	0	0	0	0
7	19	5	0.0	2	1	0	1	0
7	20	6	0.0	2	1	0	1	0
7	21	7	0.0					
7	22	1	12.4					
7	23	2	0.0	5	2	1	1	1
7	24	3	0.0	7	2	1	1	1
7	25	hol	0.0					
7	26	5	12.2	0	0	0	0	0
7	27	6	12.7	0	0	0	0	0
7	28	7	0.0					
7	29	1	0.0					
7	30	2	0.0	11	3	1	1	1
7	31	3	0.0	11	2	1	1	1
8	1	4	1.8	8	2	1	1	1
8	2	5	0.0	4	1	1	1	1
8	3	6	0.0	4	3	1	1	1
8	4	7	23.9					

Table D.3. (cont'd).

8	5	1	0.0					
8	6	2	0.0	4	1	1	1	1
8	7	3	0.0	5	3	1	1	1
8	8	4	0.0	6	1	1	1	1
8	9	5	0.0	9	6	1	1	1
8	10	6	0.0	8	3	1	1	1
8	11	7	0.0					
8	12	1	0.0					
8	13	2	0.0	8	4	1	1	1
8	14	3	0.0	17	6	1	1	1
8	15	4	0.0	7	4	1	1	1
8	16	5	0.0	9	3	1	1	1
8	17	6	0.0	5	2	1	1	1
8	18	7	0.0					
8	19	1	0.0					
8	20	2	0.0	17	6	1	1	1
8	21	3	0.0	8	3	1	1	1
8	22	4	0.0	7	3	1	1	1
8	23	5	0.0	15	4	1	1	1
8	24	6	0.0	6	2	1	1	1
8	25	7	0.0					
8	26	1	0.0					
8	27	2	0.0	10	2	1	1	1
8	28	3	0.0	9	4	1	1	1
8	29	4	36.8	10	2	1	1	1
8	30	5	0.0	9	2	1	1	1
8	31	6	0.0	7	3	1	1	1
9	1	7	0.0					
9	2	1	25.4					
9	3	hol	0.0					
9	4	3	0.0	2	1	1	1	0
9	5	4	0.0	9	2	1	1	1
9	6	5	0.0	14	5	1	1	1
9	7	6	0.0	7	3	1	1	1
9	8	7	0.0					
9	9	1	11.2					
9	10	2	0.0	2	1	0	1	0
9	11	3	0.0	12	3	1	1	1
9	12	4	0.0	9	2	1	1	1
9	13	5	0.0	24	3	1	1	1
9	14	6	0.0	23	5	1	1	1
9	15	7	0.0					
9	16	1	37.1					
9	17	2	0.0	5	1	1	1	1
9	18	3	0.0	18	4	1	1	1
9	19	4	0.0	8	5	1	1	1
9	20	5	0.0	15	3	1	1	1
9	21	6	0.0	23	4	1	1	1
9	22	7	0.0					
9	23	1	0.0					
9	24	2	7.6	16	4	1	1	1
9	25	3	76.2	6	3	1	1	1
9	26	4	24.1	0	0	0	0	0
9	27	5	0.0	2	1	0	1	0
9	28	6	10.9	6	3	1	1	1
9	29	7	0.0					
9	30	1	0.0					
1991								
5	1	4	0.0	4	3	1	1	1

Table D.3. (cont'd).

5	2	5	0.0	4	2	1	1	1
5	3	6	0.0	6	1	1	1	1
5	4	7	0.0					
5	5	1	0.0					
5	6	2	0.0	14	3	1	1	1
5	7	3	0.0	9	2	1	1	1
5	8	4	16.5	10	5	1	1	1
5	9	5	0.0	5	3	1	1	1
5	10	6	0.0	4	2	1	1	1
5	11	7	8.9					
5	12	1	0.0					
5	13	2	0.0	14	5	1	1	1
5	14	3	0.0	0	0			*
5	15	4	0.0	18	5	1	1	1
5	16	5	0.0	10	3	1	1	1
5	17	6	0.0	15	4	1	1	1
5	18	7	6.3					
5	19	1	3.8					
5	20	2	0.0	8	4	1	1	1
5	21	3	0.0	10	5	1	1	1
5	22	4	0.0	7	2	1	1	1
5	23	5	0.0	15	4	1	1	1
5	24	6	0.0	6	2	1	1	1
5	25	7	24.1					
5	26	1	0.0					
5	27	hol	0.0					
5	28	3	0.0	12	3	1	1	1
5	29	4	0.0	9	3	1	1	1
5	30	5	0.0	16	5	1	1	1
5	31	6	0.0	2	1			*
6	1	7	0.0					
6	2	1	0.0					
6	3	2	0.0	18	6	1	1	1
6	4	3	1.3	9	4	1	1	1
6	5	4	0.0	3	1	1	1	1
6	6	5	1.0	16	4	1	1	1
6	7	6	0.0	16	5	1	1	1
6	8	7	0.0					
6	9	1	0.0					
6	10	2	0.0	30	5	1	1	1
6	11	3	4.8	14	5	1	1	1
6	12	4	0.0	10	3	1	1	1
6	13	5	0.0	12	3	1	1	1
6	14	6	0.0	0	0			*
6	15	7	0.0					
6	16	1	0.0					
6	17	2	0.0	10	4	1	1	1
6	18	3	0.0	8	3	1	1	1
6	19	4	0.0	21	5	1	1	1
6	20	5	0.0	14	3	1	1	1
6	21	6	0.0	7	3	1	1	1
6	22	7	0.0					
6	23	1	0.0					
6	24	2	0.0	9	2	1	1	1
6	25	3	0.0	12	3	1	1	1
6	26	4	0.0	14	4	1	1	1
6	27	5	0.0	11	5	1	1	1
6	28	6	0.0	12	4	1	1	1
6	29	7	0.0					

Table D.3. (cont'd).

6	30	1	0.0					
7	1	2	0.0	14	3	1	1	1
7	2	3	0.0	8	2	1	1	1
7	3	4	0.0	1	1	0	1	0
7	4	hol	10.2					
7	5	6	0.0	7	1	1	1	1
7	6	7	0.0					
7	7	1	0.0					
7	8	2	0.0	7	1	1	1	1
7	9	3	0.0	11	3	1	1	1
7	10	4	0.0	3	1	1	1	1
7	11	5	0.0	6	2	1	1	1
7	12	6	0.0	7	1	1	1	1
7	13	7	0.0					
7	14	1	0.0					
7	15	2	34.3	13	4	1	1	1
7	16	3	0.0	0	0	0	0	0
7	17	hol	0.0					
7	18	5	0.0	1	1	0	1	0
7	19	6	0.0	5	1	1	1	1
7	20	7	0.0					
7	21	1	0.0					
7	22	2	5.6	6	2	1	1	1
7	23	3	0.0	7	2	1	1	1
7	24	4	0.0	11	2	1	1	1
7	25	hol	0.0					
7	26	6	0.0	16	3	1	1	1
7	27	7	0.0					
7	28	1	5.1					
7	29	2	0.0	4	1	1	1	1
7	30	3	0.0	9	2	1	1	1
7	31	4	0.0	9	2	1	1	1
8	1	5	0.0	11	2	1	1	1
8	2	6	0.0	12	4	1	1	1
8	3	7	0.0					
8	4	1	24.4					
8	5	2	0.0	13	3	1	1	1
8	6	3	0.0	13	3	1	1	1
8	7	4	0.0	13	5	1	1	1
8	8	5	0.0	12	3	1	1	1
8	9	6	0.0	15	4	1	1	1
8	10	7	0.0					
8	11	1	0.0					
8	12	2	0.0	16	5	1	1	1
8	13	3	0.0	14	4	1	1	1
8	14	4	0.0	12	3	1	1	1
8	15	5	0.0	12	4	1	1	1
8	16	6	0.0	11	3	1	1	1
8	17	7	0.0					
8	18	1	0.0					
8	19	2	0.0	13	5	1	1	1
8	20	3	0.0	9	2	1	1	1
8	21	4	0.0	15	3	1	1	1
8	22	5	50.8	0	0	0	0	0
8	23	6	0.0	0	0	0	0	0
8	24	7	0.0					
8	25	1	0.0					
8	26	2	0.0	0	0	0	0	0

Table D.3. (cont'd).

8	27	3	2.3	8	2	1	1	1
8	28	4	5.1	9	4	1	1	1
8	29	5	0.0	13	2	1	1	1
8	30	6	0.0	12	2	1	1	1
8	31	7	0.0					
9	1	1	0.0					
9	2	hol	0.0					
9	3	3	0.0	19	6	1	1	1
9	4	4	0.0	12	4	1	1	1
9	5	5	0.0	12	3	1	1	1
9	6	6	0.0	5	2	1	1	1
9	7	7	0.0					
9	8	1	8.9					
9	9	2	0.0	6	3	1	1	1
9	10	3	0.0	3	1	1	1	1
9	11	4	0.0	4	1	1	1	1
9	12	5	0.0	10	3	1	1	1
9	13	6	0.0	7	2	1	1	1
9	14	7	0.0					
9	15	1	23.9					
9	16	2	0.0	0	0	0	0	0
9	17	3	28.4	0	0	0	0	0
9	18	4	0.0	0	0	0	0	0
9	19	5	0.0	14	4	1	1	1
9	20	6	0.0	12	5	1	1	1
9	21	7	0.0					
9	22	1	0.0					
9	23	2	3.0	0	0			*
9	24	3	0.0	11	3	1	1	1
9	25	4	0.0	11	3	1	1	1
9	26	5	0.0	19	7	1	1	1
9	27	6	0.0	15	4	1	1	1
9	28	7	0.0					
9	29	1	0.0					
9	30	2	0.0	10	4	1	1	1

Table D.4 Observed non-tillage operations data and definition of working days for the Guanica Valley vegetable field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

					MEAN		REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)		
					OCTOBER TO APRIL (ON-SEASON)				
NUMBER OF REPORTED DAYS [‡] =					282				
TOTAL HOURS =					2497				
TOTAL OPERATIONS (op.) =					714				
					9 h/day		3 h/day		
					3 op./day		1 op./day		
DATE			DAY OF THE WEEK [§]	PREC. (mm)	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY			h/day	op./day	h/day [¶]	op./day [§]	W, NW [†]
1989	10	1	1	15.5					
	10	2	2	0.0	0	0	0	0	0
	10	3	3	0.0	8	2	1	1	1
	10	4	4	0.0	8	2	1	1	1
	10	5	5	0.0	2	1			*
	10	6	6	0.0	4	4	1	1	1
	10	7	7	0.0					
	10	8	1	0.0					
	10	9	2	0.0	2	1			*
	10	10	3	0.0	2	1			*
	10	11	4	0.0	0	0			*
	10	12	hol**	0.0					
	10	13	6	0.0	10	3	1	1	1
	10	14	7	0.0					
	10	15	1	0.0					
	10	16	2	0.0	1	1			*
	10	17	3	0.0	2	1			*
	10	18	4	0.0	1	1			*
	10	19	5	0.0	1	1	0	0	0
	10	20	6	19.0	2	1	0	1	0
	10	21	7	0.0					

- ‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.
 § - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.
 ¶ - Working or non working day base on number of hours per day (1 or 0 respectively).
 § - Working or non working day base on number of operations per day (1 or 0 respectively).
 † - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).
 * - The observed day was not considered as observed data.
 ** - Holiday

Table D.4. (cont'd).

10	22	1	0.0					
10	23	2	0.0	0	0	0	0	0
10	24	3	0.0	0	0	0	0	0
10	25	4	0.0	10	4	1	1	1
10	26	5	0.0	7	2	1	1	1
10	27	6	0.0	3	2	1	1	1
10	28	7	0.0					
10	29	1	0.0					
10	30	2	0.0	14	2	1	1	1
10	31	3	0.0	21	5	1	1	1
11	1	4	0.0	29	13	1	1	1
11	2	5	5.1	10	5	1	1	1
11	3	6	17.8	12	7	1	1	1
11	4	7	0.0					
11	5	1	15.2					
11	6	2	8.9	6	3	1	1	1
11	7	3	34.3	0	0	0	0	0
11	8	4	2.5	0	0	0	0	0
11	9	5	0.0	0	0	0	0	0
11	10	6	0.0	0	0	0	0	0
11	11	7	0.0					
11	12	1	0.0					
11	13	2	15.2	6	2	1	1	1
11	14	3	19.0	0	0	0	0	0
11	15	4	0.0	0	0	0	0	0
11	16	5	19.6	0	0	0	0	0
11	17	6	0.0	12	3	1	1	1
11	18	7	0.0					
11	19	1	0.0					
11	20	2	0.0	0	0			*
11	21	3	0.0	6	2	1	1	1
11	22	4	0.0	6	2	1	1	1
11	23	hol	0.0					
11	24	6	0.0	0	0			*
11	25	7	0.0					
11	26	1	0.0					
11	27	2	0.0	4	1	1	1	1
11	28	3	0.0	0	0			*
11	29	4	0.0	0	0			*
11	30	5	0.0	3	2	1	1	1
12	1	6	0.0	2	1			*
12	2	7	0.0					
12	3	1	0.0					
12	4	2	0.0	0	0			*
12	5	3	0.0	4	1	1	1	1
12	6	4	0.0	4	1	1	1	1
12	7	5	0.0	1	1			*
12	8	6	0.0	4	1	1	1	1
12	9	7	0.0					
12	10	1	0.0					
12	11	2	0.0	0	0			*
12	12	3	0.0	0	0			*
12	13	4	0.0	4	1	1	1	1
12	14	5	0.0	4	1	1	1	1
12	15	6	0.0	0	0			*
12	16	7	0.0					
12	17	1	0.0					
12	18	2	0.0	2	1			*

Table D.4. (cont'd).

1990	12	19	3	0.0	5	1	1	1	1
	12	20	4	0.0	1	1			*
	12	21	5	0.0	5	1	1	1	1
	12	22	6	0.0	6	2	1	1	1
	12	23	7	0.0					
	12	24	1	0.0					
	12	25	hol	0.0					
	12	26	3	0.0	6	1	1	1	1
	12	27	4	0.0	11	2	1	1	1
	12	28	5	0.0	4	2	1	1	1
	12	29	6	0.0	11	2	1	1	1
	12	30	7	0.0					
	12	31	1	0.0					
	1	1	hol	3.3					
	1	2	3	0.0	4	1	1	1	1
	1	3	4	0.0	5	3	1	1	1
	1	4	5	0.0	5	2	1	1	1
	1	5	6	0.0	11	4	1	1	1
	1	6	7	0.0					
	1	7	1	0.0					
	1	8	2	0.0	3	1	1	1	1
	1	9	3	0.0	3	1	1	1	1
	1	10	4	0.0	5	2	1	1	1
	1	11	hol	0.0					
	1	12	6	0.0	5	1	1	1	1
	1	13	7	0.0					
	1	14	1	0.0					
	1	15	hol	0.0					
	1	16	3	0.0	6	2	1	1	1
	1	17	4	0.0	0	0			*
	1	18	5	0.0	5	2	1	1	1
	1	19	6	0.0	5	1	1	1	1
	1	20	7	0.0					
	1	21	1	0.0					
	1	22	2	0.0	6	3	1	1	1
	1	23	3	0.0	5	2	1	1	1
	1	24	4	0.0	7	2	1	1	1
	1	25	5	0.0	6	1	1	1	1
	1	26	6	0.0	5	2	1	1	1
	1	27	7	0.0					
	1	28	1	0.0					
	1	29	2	0.0	2	1			*
	1	30	3	0.0	6	1	1	1	1
	1	31	4	0.0	5	1	1	1	1
	2	1	5	0.0	2	1			*
	2	2	6	0.0	9	3	1	1	1
	2	3	7	0.0					
	2	4	1	0.0					
	2	5	2	0.0	4	2	1	1	1
	2	6	3	0.0	4	2	1	1	1
	2	7	4	0.0	6	2	1	1	1
	2	8	5	0.0	6	3	1	1	1
	2	9	6	0.0	3	1	1	1	1
	2	10	7	0.0					
	2	11	1	2.5					
	2	12	2	0.0	16	4	1	1	1
	2	13	3	0.0	5	2	1	1	1
	2	14	4	0.0	4	2	1	1	1

Table D.4. (cont'd).

2	15	5	0.0	3	1	1	1	1
2	16	6	0.0	10	4	1	1	1
2	17	7	0.0					
2	18	1	0.0					
2	19	hol	0.0					
2	20	3	0.0	5	2	1	1	1
2	21	4	0.0	16	5	1	1	1
2	22	5	0.0	10	3	1	1	1
2	23	6	0.0	6	2	1	1	1
2	24	7	0.0					
2	25	1	0.0					
2	26	2	0.0	18	3	1	1	1
2	27	3	0.0	24	6	1	1	1
2	28	4	0.0	43	8	1	1	1
3	1	5	1.3	15	3	1	1	1
3	2	6	0.0	12	2	1	1	1
3	3	7	0.0					
3	4	1	0.0					
3	5	2	0.0	16	4	1	1	1
3	6	3	0.0	17	5	1	1	1
3	7	4	0.0	5	2	1	1	1
3	8	5	0.0	9	3	1	1	1
3	9	6	0.0	7	4	1	1	1
3	10	7	22.9					
3	11	1	6.3					
3	12	2	0.0	4	1	1	1	1
3	13	3	0.0	2	1	0	1	0
3	14	4	0.0	10	2	1	1	1
3	15	5	0.0	2	1	0	1	0
3	16	6	0.0	22	6	1	1	1
3	17	7	0.0					
3	18	1	0.0					
3	19	2	0.0	3	2	1	1	1
3	20	3	0.0	4	2	1	1	1
3	21	4	0.0	7	2	1	1	1
3	22	hol	0.0					
3	23	6	0.0	7	4	1	1	1
3	24	7	0.0					
3	25	1	0.0					
3	26	2	0.0	11	3	1	1	1
3	27	3	1.8	2	1			*
3	28	4	0.0	0	0			*
3	29	5	0.0	3	2	1	1	1
3	30	6	0.0	2	1			*
3	31	7	0.0					
4	1	1	0.0					
4	2	2	0.0	12	3	1	1	1
4	3	3	0.0	7	2	1	1	1
4	4	4	0.0	18	5	1	1	1
4	5	5	0.0	6	3	1	1	1
4	6	6	0.0	14	5	1	1	1
4	7	7	0.0					
4	8	1	0.0					
4	9	2	0.0	5	3	1	1	1
4	10	3	0.0	8	2	1	1	1
4	11	4	0.0	8	5	1	1	1
4	12	hol	0.0					
4	13	hol	0.0					

Table D.4. (cont'd).

4	14	7	0.0					
4	15	1	0.0					
4	16	hol	0.0					
4	17	3	0.0	14	4	1	1	1
4	18	4	0.0	24	7	1	1	1
4	19	5	65.5	9	3	1	1	1
4	20	6	0.0	2	2	0	1	0
4	21	7	0.0					
4	22	1	0.0					
4	23	2	0.0	25	6	1	1	1
4	24	3	0.0	2	1	0	1	0
4	25	4	4.8	28	7	1	1	1
4	26	5	0.0	4	2	1	1	1
4	27	6	0.0	2	1			*
4	28	7	0.0					
4	29	1	0.0					
4	30	2	0.0	2	1			*
10	1	2	0.0	20	4	1	1	1
10	2	3	0.0	13	5	1	1	1
10	3	4	0.0	3	3	1	1	1
10	4	5	0.0	4	2	1	1	1
10	5	6	0.0	8	2	1	1	1
10	6	7	0.0					
10	7	1	11.7					
10	8	2	5.1	6	1	1	1	1
10	9	3	2.5	2	1	0	1	0
10	10	4	24.4	9	2	1	1	1
10	11	5	5.1	5	1	1	1	1
10	12	hol	50.8					
10	13	7	14.0					
10	14	1	14.0					
10	15	2	0.0	0	0	0	0	0
10	16	3	6.9	0	0	0	0	0
10	17	4	5.1	2	2	0	1	0
10	18	5	44.5	2	1	0	1	0
10	19	6	7.6	1	1	0	1	0
10	20	7	76.2					
10	21	1	22.9					
10	22	2	2.5	9	2	1	1	1
10	23	3	8.9	10	2	1	1	1
10	24	4	30.5	1	1	0	1	0
10	25	5	69.8	0	0	0	0	0
10	26	6	8.6	2	1	0	1	0
10	27	7	0.0					
10	28	1	17.3					
10	29	2	2.5	0	0	0	0	0
10	30	3	0.0	1	1	0	1	0
10	31	4	0.0	14	4	1	1	1
11	1	5	0.0	0	0			*
11	2	6	0.0	11	3	1	1	1
11	3	7	0.0					
11	4	1	37.6					
11	5	2	2.5	0	0	0	0	0
11	6	3	0.0	13	2	1	1	1
11	7	4	0.0	0	0	0	0	0
11	8	5	0.0	3	1	1	1	1
11	9	6	0.0	6	3	1	1	1
11	10	7	0.0					

Table D.4. (cont'd).

11	11	1	0.0					
11	12	hol	0.0					
11	13	4	0.0	5	2	1	1	1
11	14	4	0.0	0	0			*
11	15	5	0.0	5	2	1	1	1
11	16	6	21.6	3	1	1	1	1
11	17	7	3.8					
11	18	1	0.0					
11	19	hol	0.0					
11	20	3	0.0	13	3	1	1	1
11	21	4	0.0	11	3	1	1	1
11	22	hol	0.0					
11	23	6	0.0	17	3	1	1	1
11	24	7	0.0					
11	25	1	0.0					
11	26	2	0.0	5	1	1	1	1
11	27	3	0.0	22	4	1	1	1
11	28	4	0.0	31	5	1	1	1
11	29	5	0.0	16	4	1	1	1
11	30	6	0.0	3	1	1	1	1
12	1	7	0.0					
12	2	1	0.0					
12	3	2	0.0	11	3	1	1	1
12	4	3	0.0	9	2	1	1	1
12	5	4	0.0	10	2	1	1	1
12	6	5	0.0	3	1	1	1	1
12	7	6	0.0	0	0			*
12	8	7	0.0					
12	9	1	0.0					
12	10	2	0.0	1	1			*
12	11	3	0.0	9	2	1	1	1
12	12	4	0.0	7	2	1	1	1
12	13	5	0.0	0	0			*
12	14	6	0.0	8	4	1	1	1
12	15	7	0.0					
12	16	1	10.9					
12	17	2	0.0	17	4	1	1	1
12	18	3	0.0	9	3	1	1	1
12	19	4	0.0	11	2	1	1	1
12	20	5	0.0	13	4	1	1	1
12	21	6	0.0	12	3	1	1	1
12	22	7	0.0					
12	23	1	0.0					
12	24	2	0.0	0	0			*
12	25	hol	0.0					
12	26	4	0.0	8	3	1	1	1
12	27	5	0.0	7	1	1	1	1
12	28	6	0.0	3	2	1	1	1
12	29	7	0.0					
12	30	1	0.0					
12	31	2	0.0	0	0			*
1991	1	1	hol					
	1	2	4	0	0			*
	1	3	5	18	4	1	1	1
	1	4	6	9	4	1	1	1
	1	5	7					
	1	6	1					
	1	7	hol					

Table D.4. (cont'd).

1	8	3	0.0	0	0			*
1	9	4	0.0	5	1	1	1	1
1	10	5	0.0	4	1	1	1	1
1	11	hol	0.0					
1	12	7	0.0					
1	13	1	0.0					
1	14	2	0.0	9	2	1	1	1
1	15	3	0.0	10	4	1	1	1
1	16	4	0.0	5	1	1	1	1
1	17	5	0.0	9	2	1	1	1
1	18	6	0.0	10	2	1	1	1
1	19	7	0.0					
1	20	1	0.0					
1	21	2	0.0	21	7	1	1	1
1	22	3	0.0	5	3	1	1	1
1	23	4	0.0	0	0			*
1	24	5	0.0	13	3	1	1	1
1	25	6	0.0	8	6	1	1	1
1	26	7	0.0					
1	27	1	0.0					
1	28	2	0.0	5	2	1	1	1
1	29	3	0.0	8	2	1	1	1
1	30	4	0.0	11	4	1	1	1
1	31	5	0.0	3	1	1	1	1
2	1	6	0.0	7	2	1	1	1
2	2	7	0.0					
2	3	1	0.0					
2	4	2	0.0	6	3	1	1	1
2	5	3	0.0	6	3	1	1	1
2	6	4	0.0	7	2	1	1	1
2	7	5	0.0	4	2	1	1	1
2	8	6	0.0	1	1			*
2	9	7	0.0					
2	10	1	17.3					
2	11	2	11.4	7	2	1	1	1
2	12	3	3.6	0	0	0	0	0
2	13	4	3.3	7	1	1	1	1
2	14	5	0.0	18	3	1	1	1
2	15	6	0.0	7	2	1	1	1
2	16	7	0.0					
2	17	1	0.0					
2	18	hol	0.0					
2	19	3	0.0	2	1			*
2	20	4	0.0	10	3	1	1	1
2	21	5	0.0	48	4	1	1	1
2	22	6	0.0	9	3	1	1	1
2	23	7	0.0					
2	24	1	0.0					
2	25	2	0.0	21	4	1	1	1
2	26	3	0.0	18	4	1	1	1
2	27	4	0.0	21	4	1	1	1
2	28	5	0.0	3	2	1	1	1
3	1	6	0.0	3	2	1	1	1
3	2	7	0.0					
3	3	1	2.5					
3	4	2	3.8	17	3	1	1	1
3	5	3	0.0	13	4	1	1	1
3	6	4	0.0	16	4	1	1	1

Table D.4. (cont'd).

3	7	5	0.0	12	3	1	1	1
3	8	6	0.0	13	3	1	1	1
3	9	7	0.0					
3	10	1	0.0					
3	11	2	0.0	22	5	1	1	1
3	12	3	0.0	8	3	1	1	1
3	13	4	0.0	11	3	1	1	1
3	14	5	0.0	33	8	1	1	1
3	15	6	0.0	11	3	1	1	1
3	16	7	0.0					
3	17	1	0.0					
3	18	2	42.4	12	3	1	1	1
3	19	3	0.0	9	2	1	1	1
3	20	4	0.0	6	2	1	1	1
3	21	5	12.2	7	2	1	1	1
3	22	hol	12.2					
3	23	7	0.0					
3	24	1	0.0					
3	25	2	0.0	14	4	1	1	1
3	26	3	29.2	19	5	1	1	1
3	27	4	0.0	5	2	1	1	1
3	28	hol	0.0					
3	29	hol	0.0					
3	30	7	0.0					
3	31	1	0.0					
4	1	2	0.0	24	5	1	1	1
4	2	3	0.0	15	3	1	1	1
4	3	4	0.0	32	7	1	1	1
4	4	5	0.0	25	6	1	1	1
4	5	6	10.9	20	4	1	1	1
4	6	7	23.1					
4	7	1	13.2					
4	8	2	0.0	18	5	1	1	1
4	9	3	0.0	17	4	1	1	1
4	10	4	0.0	8	2	1	1	1
4	11	5	0.0	14	2	1	1	1
4	12	6	0.0	22	5	1	1	1
4	13	7	0.0					
4	14	1	0.0					
4	15	2	0.0	7	1	1	1	1
4	16	hol	0.0					
4	17	4	0.0	14	2	1	1	1
4	18	5	0.0	14	2	1	1	1
4	19	6	0.0	17	4	1	1	1
4	20	7	0.0					
4	21	1	0.0					
4	22	2	0.0	13	5	1	1	1
4	23	3	0.0	9	2	1	1	1
4	24	4	0.0	12	3	1	1	1
4	25	5	0.0	17	3	1	1	1
4	26	6	0.0	11	3	1	1	1
4	27	7	0.0					
4	28	1	0.0					
4	29	2	0.0	10	3	1	1	1
4	30	3	0.0	25	6	1	1	1
10	1	3	0.0	6	2	1	1	1
10	2	4	0.0	8	2	1	1	1
10	3	5	0.0	9	2	1	1	1

Table D.4. (cont'd).

10	4	6	0.0	2	1			*
10	5	7	0.0					
10	6	1	23.9					
10	7	2	0.0	9	2	1	1	1
10	8	3	0.0	5	2	1	1	1
10	9	4	0.0	12	3	1	1	1
10	10	5	0.0	5	2	1	1	1
10	11	6	0.0	5	2	1	1	1
10	12	hol	0.0					
10	13	1	0.0					
10	14	2	0.0	5	2	1	1	1
10	15	3	0.0	7	3	1	1	1
10	16	4	0.0	4	2	1	1	1
10	17	5	16.5	4	2	1	1	1
10	18	6	0.0	7	2	1	1	1
10	19	7	0.0					
10	20	1	0.0					
10	21	2	0.0	0	0			*
10	22	3	1.3	0	0			*
10	23	4	0.0	0	0			*
10	24	5	0.0	0	0			*
10	25	6	0.0	0	0			*
10	26	7	0.0					
10	27	1	0.0					
10	28	2	0.0	0	0			*
10	29	3	0.0	0	0			*
10	30	4	0.0	0	0			*
10	31	5	11.4	8	2	1	1	1
11	1	6	6.6	5	1	1	1	1
11	2	7	0.0					
11	3	1	0.0					
11	4	2	0.0	0	0			*
11	5	3	0.0	4	2	1	1	1
11	6	4	7.6	3	1	1	1	1
11	7	5	25.4	4	2	1	1	1
11	8	6	0.5	0	0	0	0	0
11	9	7	0.0					
11	10	1	0.0					
11	11	hol	0.0					
11	12	3	0.0	4	1	1	1	1
11	13	4	0.0	0	0			*
11	14	5	5.8	3	1	1	1	1
11	15	6	0.0	5	2	1	1	1
11	16	7	22.9					
11	17	1	25.4					
11	18	2	0.0	0	0	0	0	0
11	19	hol	0.0					
11	20	4	0.0	5	2	1	1	1
11	21	5	0.0	4	2	1	1	1
11	22	6	0.0	0	0			*
11	23	7	0.0					
11	24	1	0.0					
11	25	2	0.0	0	0			*
11	26	3	0.0	3	1	1	1	1
11	27	4	4.8	5	2	1	1	1
11	28	hol	0.0					
11	29	6	0.0	0	0			*
11	30	7	0.0					

Table D.4. (cont'd).

12	1	1	0.0					
12	2	2	0.0	0	0			*
12	3	3	0.0	0	0			*
12	4	4	0.0	5	2	1	1	1
12	5	5	0.0	7	1	1	1	1
12	6	6	0.0	7	1	1	1	1
12	7	7	0.0					
12	8	1	0.0					
12	9	2	0.0	8	2	1	1	1
12	10	3	12.7	0	0	0	0	0
12	11	4	0.0	4	2	1	1	1
12	12	5	0.0	7	1	1	1	1
12	13	6	0.0	4	1	1	1	1
12	14	7	0.0					
12	15	1	0.0					
12	16	2	0.0	10	2	1	1	1
12	17	3	0.0	13	2	1	1	1
12	18	4	0.0	8	2	1	1	1
12	19	5	0.0	2	1			*
12	20	6	0.0	7	2	1	1	1
12	21	7	0.0					
12	22	1	0.0					
12	23	2	0.0	0	0			*
12	24	3	0.0	0	0			*
12	25	hol	0.0					
12	26	5	0.0	0	0			*
12	27	6	0.0	0	0			*
12	28	7	0.0					
12	29	1	0.0					
12	30	2	0.0	5	2	1	1	1
12	31	3	0.5	11	3	1	1	1

Table D.5 Observed tillage operations data and definition of working days for the Santa Isabel Valley tomato field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

					MEAN	REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)			
AUGUST TO SEPTEMBER (ON-SEASON)									
NUMBER OF REPORTED DAYS* = 74									
TOTAL HOURS = 889					12 h/day		4 h/day		
TOTAL OPERATIONS (op.) = 191					3 op./day		1 op./day		
DATE			DAY OF THE WEEK*	PREC.	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY		(mm)	h/day	op./day	h/day [†]	op./day [‡]	W, NW [†]
1989									
	9	1	6	0.0					*
	9	2	7	0.0					
	9	3	1	0.0					
	9	4	2	0.0	8	2	1	1	1
	9	5	3	0.0	11	3	1	1	1
	9	6	4	0.0	9	2	1	1	1
	9	7	5	0.0	11	2	1	1	1
	9	8	6	0.0	9	3	1	1	1
	9	9	7	0.0					
	9	10	1	0.0					
	9	11	2	28.2	0	0	0	0	0
	9	12	3	0.0	10	2	1	1	1
	9	13	4	0.0	7	2	1	1	1
	9	14	5	0.0	5	2	1	1	1
	9	15	6	6.3	18	3	1	1	1
	9	16	7	0.0					
	9	17	1	0.0					
	9	18	2	10.2	0	0	0	0	0
	9	19	3	12.7	0	0	0	0	0
	9	20	4	0.0	0	0	0	0	0

- ‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.
 § - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.
 ¶ - Working or non working day base on number of hours per day (1 or 0 respectively).
 § - Working or non working day base on number of operations per day (1 or 0 respectively).
 † - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).
 * - The observed day was not considered as observed data.
 ** - Holiday

Table D.5. (cont'd).

1990	9	21	5	17.0	0	0	0	0	0
	9	22	6	21.3	0	0	0	0	0
	9	23	7	54.1					
	9	24	1	10.2					
	9	25	2	0.0	0	0	0	0	0
	9	26	3	0.0	16	5	1	1	1
	9	27	4	0.0	11	4	1	1	1
	9	28	5	0.0	9	2	1	1	1
	9	29	6	0.0	9	3	1	1	1
	9	30	7	0.0					
	8	1	4	0.0	16	3	1	1	1
	8	2	5	0.0	10	3	1	1	1
	8	3	6	2.5	0	0			*
	8	4	7	0.0					
	8	5	1	0.0					
	8	6	2	0.0	19	3	1	1	1
	8	7	3	3.8	11	2	1	1	1
	8	8	4	2.5	13	2	1	1	1
	8	9	5	0.0	20	3	1	1	1
	8	10	6	7.6	17	3	1	1	1
	8	11	7	0.0					
	8	12	1	0.0					
	8	13	2	1.5	13	2	1	1	1
	8	14	3	0.0	6	2	1	1	1
	8	15	4	0.0	14	2	1	1	1
	8	16	5	0.0	10	2	1	1	1
	8	17	6	0.0	7	2	1	1	1
	8	18	7	0.0					
	8	19	1	0.0					
	8	20	2	0.0	7	2	1	1	1
	8	21	3	0.0	0	0			*
	8	22	4	0.0	0	0			*
	8	23	5	0.0	0	0			*
	8	24	6	0.0	0	0			*
	8	25	7	0.0					
	8	26	1	0.0					
	8	27	2	0.0	6	2	1	1	1
	8	28	3	0.0	8	2	1	1	1
	8	29	4	15.2	0	0	0	0	0
	8	30	5	0.0	0	0	0	0	0
	8	31	6	0.0	0	0	0	0	0
	9	1	7	0.0					
	9	2	1	15.2					
	9	3	hol**	0.0					
	9	4	3	0.0	0	0	0	0	0
	9	5	4	0.0	12	2	1	1	1
	9	6	5	0.0	13	2	1	1	1
	9	7	6	0.0	10	2	1	1	1
	9	8	7	0.0					
	9	9	1	0.0					
	9	10	2	0.0	10	2	1	1	1
	9	11	3	0.0	11	2	1	1	1
	9	12	4	0.0	9	2	1	1	1
	9	13	5	0.0	8	3	1	1	1
	9	14	6	0.0	7	2	1	1	1
	9	15	7	15.2					
	9	16	1	10.2					

Table D.5. (cont'd).

1991	9	17	2	0.0	0	0	0	0	0
	9	18	3	0.0	6	2	1	1	1
	9	19	4	0.0	9	2	1	1	1
	9	20	5	0.0	13	4	1	1	1
	9	21	6	0.0	19	4	1	1	1
	9	22	7	0.0					
	9	23	1	0.0					
	9	24	2	0.0	8	2	1	1	1
	9	25	3	6.3	14	3	1	1	1
	9	26	4	0.0	8	2	1	1	1
	9	27	5	0.0	13	2	1	1	1
	9	28	6	17.8	7	2	1	1	1
	9	29	7	15.2					
	9	30	1	0.0					
	8	1	1	0.0	0	0			*
	8	2	6	0.0	0	0			*
	8	3	7	0.0					
	8	4	1	0.0					
	8	5	2	0.0	12	2	1	1	1
	8	6	3	0.0	10	2	1	1	1
	8	7	4	0.0	15	3	1	1	1
	8	8	5	0.0	10	2	1	1	1
	8	9	6	0.0	8	2	1	1	1
	8	10	7	0.0					
	8	11	1	0.0					
	8	12	2	7.6	26	4	1	1	1
	8	13	3	0.0	27	5	1	1	1
	8	14	4	0.0	9	2	1	1	1
	8	15	5	0.0	10	2	1	1	1
	8	16	6	0.0	13	2	1	1	1
	8	17	7	0.0					
	8	18	1	0.0					
	8	19	2	0.0	14	3	1	1	1
	8	20	3	0.0	9	2	1	1	1
	8	21	4	0.0	0	0	0	0	0
	8	22	5	0.0	0	0	0	0	0
	8	23	6	57.1	0	0	0	0	0
	8	24	7	0.0					
	8	25	1	0.0					
	8	26	2	0.0	18	3	1	1	1
	8	27	3	8.9	14	3	1	1	1
	8	28	4	0.0	12	2	1	1	1
	8	29	5	0.0	21	4	1	1	1
	8	30	6	7.6	20	4	1	1	1
	8	31	7	0.0					
	9	1	1	0.0					
	9	2	hol	0.0					
	9	3	3	0.0	10	2	1	1	1
	9	4	4	0.0	10	2	1	1	1
	9	5	5	0.0	12	2	1	1	1
	9	6	6	0.0	11	2	1	1	1
	9	7	7	0.0					
	9	8	1	0.0					
	9	9	2	0.0	10	2	1	1	1
	9	10	3	2.5	0	0			*
	9	11	4	0.0	9	2	1	1	1
	9	12	5	0.0	11	2	1	1	1
	9	13	6	0.0	10	2	1	1	1

Table D.5. (cont'd).

9	14	7	0.0					
9	15	1	0.0					
9	16	2	25.4	11	2	1	1	1
9	17	3	12.7	0	0	0	0	0
9	18	4	0.0	0	0	0	0	0
9	19	5	0.0	0	0	0	0	0
9	20	6	0.0	0	0	0	0	0
9	21	7	0.0					
9	22	1	26.7					
9	23	2	0.0	0	0	0	0	0
9	24	3	0.0	0	0	0	0	0
9	25	4	0.0	0	0	0	0	0
9	26	5	0.0	7	2	1	1	1
9	27	6	0.0	22	6	1	1	1
9	28	7	0.0					
9	29	1	0.0					
9	30	2	0.0	31	8	1	1	1

Table D.6 Observed non-tillage operations data and definition of working days for the Santa Isabel Valley tomato field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH HOURS/DAY OR OPERATIONS/DAY VALUES LESS THAN 33% OF THE MEAN

					MEAN	REJECTION VALUE (DECLARE A NON WORKING DAY A DAY WITH ANY VALUE LESS THAN)			
<u>OCTOBER TO MAY (ON-SEASON)</u>									
NUMBER OF REPORTED DAYS [‡] =					346				
TOTAL HOURS =					11776	34 h/day	11 h/day		
TOTAL OPERATIONS (op.) =					2334	7 op./day	2 op./day		
DATE			DAY OF THE WEEK [§]	PREC.	OBSERVED DATA		WORKING DAY DECISION		
YEAR	MONTH	DAY		(mm)	h/day	op./day	h/day [†]	op./day [§]	W,NW [†]
1989									
	10	1	1	0.0					
	10	2	2	6.9	12	3	1	1	1
	10	3	3	0.0	6	1			*
	10	4	4	0.0	13	2	1	1	1
	10	5	5	0.0	6	1			*
	10	6	6	0.0	6	1			*
	10	7	7	0.0					
	10	8	1	0.0					
	10	9	2	0.0	5	1			*
	10	10	3	0.0	6	1			*
	10	11	4	0.0	0	0			*
	10	12	hol**	0.0					
	10	13	6	0.0	7	1			*
	10	14	7	0.0					
	10	15	1	0.0					
	10	16	2	0.0	11	2	1	1	1
	10	17	3	0.0	14	2	1	1	1
	10	18	4	0.0	13	3	1	1	1
	10	19	5	5.6	0	0	0	0	0
	10	20	6	2.8	2	1	0	0	0

‡ - Include reported days with a minimum of one hour/day, or a minimum of one operation/day.

§ - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.

¶ - Working or non working day base on number of hours per day (1 or 0 respectively).

§ - Working or non working day base on number of operations per day (1 or 0 respectively).

† - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).

* - The observed day was not considered as observed data.

** - Holiday

Table D.6. (cont'd).

10	21	7	0.0					
10	22	1	0.0					
10	23	2	0.0	12	3	1	1	1
10	24	3	0.0	12	2	1	1	1
10	25	4	0.0	13	3	1	1	1
10	26	5	0.0	12	2	1	1	1
10	27	6	0.0	3	1			*
10	28	7	0.0					
10	29	1	0.0					
10	30	2	0.0	12	3	1	1	1
10	31	3	0.0	15	3	1	1	1
11	1	4	0.0	19	4	1	1	1
11	2	5	0.0	11	4	1	1	1
11	3	6	0.0	3	1			*
11	4	7	0.0					
11	5	1	0.0					
11	6	2	0.0	0	0			*
11	7	3	0.0	17	5	1	1	1
11	8	4	0.0	18	5	1	1	1
11	9	5	0.0	15	2	1	1	1
11	10	6	0.0	16	3	1	1	1
11	11	7	0.0					
11	12	1	0.0					
11	13	2	0.0	18	4	1	1	1
11	14	3	0.0	15	4	1	1	1
11	15	4	0.0	20	4	1	1	1
11	16	5	0.0	5	1			*
11	17	6	0.0	15	4	1	1	1
11	18	7	0.0					
11	19	1	0.0					
11	20	2	0.0	3	1			*
11	21	3	0.0	25	5	1	1	1
11	22	4	0.0	29	8	1	1	1
11	23	hol	0.0					
11	24	6	0.0	0	0			*
11	25	7	0.0					
11	26	1	0.0					
11	27	2	0.0	28	6	1	1	1
11	28	3	0.0	25	6	1	1	1
11	29	4	0.0	32	7	1	1	1
11	30	5	0.0	31	7	1	1	1
12	1	6	0.0	29	6	1	1	1
12	2	7	0.0					
12	3	1	0.0					
12	4	2	5.1	30	5	1	1	1
12	5	3	0.0	15	3	1	1	1
12	6	4	0.0	20	5	1	1	1
12	7	5	0.0	26	4	1	1	1
12	8	6	0.0	22	4	1	1	1
12	9	7	0.0					
12	10	1	0.0					
12	11	2	0.0	23	4	1	1	1
12	12	3	0.0	19	5	1	1	1
12	13	4	0.0	17	4	1	1	1
12	14	5	0.0	29	6	1	1	1
12	15	6	0.0	12	4	1	1	1
12	16	7	0.0					
12	17	1	0.0					

Table D.6. (cont'd).

12	18	2	0.0	17	3	1	1	1
12	19	3	0.0	25	6	1	1	1
12	20	4	0.0	25	6	1	1	1
12	21	5	0.0	30	6	1	1	1
12	22	6	0.0	0	0			*
12	23	7	0.0					
12	24	1	0.0					
12	25	hol	0.0					
12	26	3	0.0	26	5	1	1	1
12	27	4	0.0	19	4	1	1	1
12	28	5	0.0	28	7	1	1	1
12	29	6	0.0	33	6	1	1	1
12	30	7	10.9					
12	31	1	0.0					
1990								
1	1	hol	0.0					
1	2	3	0.0	22	4	1	1	1
1	3	4	0.0	18	4	1	1	1
1	4	5	0.0	20	5	1	1	1
1	5	6	0.0	8	3			*
1	6	7	0.0					
1	7	1	0.0					
1	8	2	0.0	25	5	1	1	1
1	9	3	0.0	31	6	1	1	1
1	10	4	0.0	17	4	1	1	1
1	11	hol	0.0					
1	12	6	0.0	33	7	1	1	1
1	13	7	3.3					
1	14	1	0.0					
1	15	hol	0.0					
1	16	3	0.0	42	7	1	1	1
1	17	4	0.0	19	4	1	1	1
1	18	5	0.0	32	6	1	1	1
1	19	6	0.0	27	5	1	1	1
1	20	7	0.0					
1	21	1	8.9					
1	22	2	0.0	37	6	1	1	1
1	23	3	0.0	32	6	1	1	1
1	24	4	0.0	30	6	1	1	1
1	25	5	0.0	29	7	1	1	1
1	26	6	0.0	36	7	1	1	1
1	27	7	0.0					
1	28	1	0.0					
1	29	2	0.0	46	9	1	1	1
1	30	3	0.0	48	8	1	1	1
1	31	4	0.0	47	8	1	1	1
2	1	5	0.0	45	8	1	1	1
2	2	6	0.0	30	6	1	1	1
2	3	7	0.0					
2	4	1	0.0					
2	5	2	0.0	47	8	1	1	1
2	6	3	0.0	44	8	1	1	1
2	7	4	0.0	42	8	1	1	1
2	8	5	0.5	41	7	1	1	1
2	9	6	0.0	41	7	1	1	1
2	10	7	0.0					
2	11	1	0.0					
2	12	2	0.0	39	7	1	1	1
2	13	3	3.3	28	6	1	1	1

Table D.6. (cont'd).

2	14	4	0.0	39	6	1	1	1
2	15	5	0.0	41	8	1	1	1
2	16	6	0.0	26	7	1	1	1
2	17	7	0.0					
2	18	1	0.0					
2	19	hol	0.0					
2	20	3	0.0	54	10	1	1	1
2	21	4	0.0	27	6	1	1	1
2	22	5	0.0	39	7	1	1	1
2	23	6	0.0	54	10	1	1	1
2	24	7	0.0					
2	25	1	0.0					
2	26	2	0.0	41	7	1	1	1
2	27	3	0.0	41	8	1	1	1
2	28	4	0.0	44	8	1	1	1
3	1	5	0.0	42	8	1	1	1
3	2	6	0.0	49	8	1	1	1
3	3	7	0.0					
3	4	1	0.0					
3	5	2	0.0	43	7	1	1	1
3	6	3	0.0	41	9	1	1	1
3	7	4	0.0	43	8	1	1	1
3	8	5	0.0	27	6	1	1	1
3	9	6	0.0	39	8	1	1	1
3	10	7	0.0					
3	11	1	0.0					
3	12	2	0.0	45	8	1	1	1
3	13	3	0.0	44	8	1	1	1
3	14	4	1.3	29	5	1	1	1
3	15	5	0.0	39	6	1	1	1
3	16	6	0.0	36	8	1	1	1
3	17	7	0.0					
3	18	1	0.0					
3	19	2	0.0	48	8	1	1	1
3	20	3	0.0	38	6	1	1	1
3	21	4	0.0	34	7	1	1	1
3	22	hol	0.0					
3	23	6	0.0	46	8	1	1	1
3	24	7	0.0					
3	25	1	0.0					
3	26	2	0.0	29	5	1	1	1
3	27	3	0.0	27	5	1	1	1
3	28	4	0.0	21	4	1	1	1
3	29	5	0.0	6	1			*
3	30	6	0.0	9	2			*
3	31	7	0.0					
4	1	1	0.0					
4	2	2	13.0	24	5	1	1	1
4	3	3	0.0	20	4	1	1	1
4	4	4	0.0	15	3	1	1	1
4	5	5	0.0	17	4	1	1	1
4	6	6	0.0	13	3	1	1	1
4	7	7	0.0					
4	8	1	0.0					
4	9	2	0.0	12	3	1	1	1
4	10	3	0.0	5	2			*
4	11	4	0.0	8	3			*
4	12	hol	0.0					

Table D.6. (cont'd).

4	13	hol	0.0					
4	14	7	0.0					
4	15	1	0.0					
4	16	hol	0.0					
4	17	3	0.0	17	3	1	1	1
4	18	4	0.0	17	3	1	1	1
4	19	5	0.0	16	3	1	1	1
4	20	6	0.0	2	1			*
4	21	7	0.0					
4	22	1	0.0					
4	23	2	0.0	3	1			*
4	24	3	0.0	8	2			*
4	25	4	11.9	9	2	0	1	0
4	26	5	0.0	5	1	0	0	0
4	27	6	1.3	0	0			*
4	28	7	0.0					
4	29	1	0.0					
4	30	2	0.0	7	1			*
10	1	2	0.0	4	1	0	0	0
10	2	3	0.0	4	1	0	0	0
10	3	4	6.3	9	2	0	1	0
10	4	5	0.0	15	3	1	1	1
10	5	6	0.0	13	2	1	1	1
10	6	7	5.1					
10	7	1	7.6					
10	8	2	17.8	2	1	0	0	0
10	9	3	22.9	5	1	0	0	0
10	10	4	17.8	5	1	0	0	0
10	11	5	0.0	0	0	0	0	0
10	12	hol	19.0					
10	13	7	5.1					
10	14	1	27.9					
10	15	2	0.0	0	0	0	0	0
10	16	3	12.7	0	0	0	0	0
10	17	4	1.3	0	0	0	0	0
10	18	5	0.0	0	0	0	0	0
10	19	6	20.3	0	0	0	0	0
10	20	7	66.0					
10	21	1	31.8					
10	22	2	27.9	0	0	0	0	0
10	23	3	0.0	0	0	0	0	0
10	24	4	22.9	0	0	0	0	0
10	25	5	0.0	0	0	0	0	0
10	26	6	26.7	0	0	0	0	0
10	27	7	12.7					
10	28	1	2.5					
10	29	2	5.1	0	0	0	0	0
10	30	3	22.9	0	0	0	0	0
10	31	4	10.9	0	0	0	0	0
11	1	5	0.0	0	0	0	0	0
11	2	6	0.0	0	0	0	0	0
11	3	7	0.0					
11	4	1	0.0					
11	5	2	10.2	0	0	0	0	0
11	6	3	6.3	14	2	1	1	1
11	7	4	0.0	4	1	0	0	0
11	8	5	0.0	13	3	1	1	1
11	9	6	0.0	15	2	1	1	1

Table D.6. (cont'd).

11	10	7	0.0					
11	11	1	0.0					
11	12	hol	0.0					
11	13	3	0.0	23	6	1	1	1
11	14	4	0.0	12	4	1	1	1
11	15	5	0.0	9	2			*
11	16	6	0.0	11	4	1	1	1
11	17	7	0.0					
11	18	1	0.0					
11	19	hol	0.0					
11	20	3	0.0	4	2			*
11	21	4	0.0	9	3			*
11	22	hol	0.0					
11	23	6	0.0	14	2	1	1	1
11	24	7	0.0					
11	25	1	0.0					
11	26	2	0.0	33	7	1	1	1
11	27	3	0.0	29	6	1	1	1
11	28	4	0.0	27	6	1	1	1
11	29	5	0.0	37	7	1	1	1
11	30	6	0.0	37	7	1	1	1
12	1	7	0.0					
12	2	1	0.0					
12	3	2	0.0	49	10	1	1	1
12	4	3	0.0	45	10	1	1	1
12	5	4	0.0	39	8	1	1	1
12	6	5	0.0	58	10	1	1	1
12	7	6	0.0	32	7	1	1	1
12	8	7	0.0					
12	9	1	0.0					
12	10	2	0.0	45	8	1	1	1
12	11	3	0.0	30	7	1	1	1
12	12	4	0.0	18	4	1	1	1
12	13	5	0.0	43	9	1	1	1
12	14	6	0.0	43	9	1	1	1
12	15	7	0.0					
12	16	1	0.0					
12	17	2	0.0	37	7	1	1	1
12	18	3	0.0	45	9	1	1	1
12	19	4	0.0	32	7	1	1	1
12	20	5	0.0	49	10	1	1	1
12	21	6	0.0	25	6	1	1	1
12	22	7	0.0					
12	23	1	25.4					
12	24	2	0.0	5	1			0
12	25	hol	0.0					
12	26	4	0.0	33	6	1	1	1
12	27	5	0.0	35	8	1	1	1
12	28	6	0.0	22	6	1	1	1
12	29	7	0.0					
12	30	1	0.0					
12	31	2	7.6	0	0			*
1991	1	hol	1.0					
	1	2	4	50	9	1	1	1
	1	3	5	69	11	1	1	1
	1	4	6	49	8	1	1	1
	1	5	7					
	1	6	1					

Table D.6. (cont'd).

1	7	hol	0.0					
1	8	3	0.0	64	12	1	1	1
1	9	4	0.0	68	14	1	1	1
1	10	5	1.5	81	15	1	1	1
1	11	hol	0.0					
1	12	7	0.0					
1	13	1	0.0					
1	14	2	0.0	48	9	1	1	1
1	15	3	0.0	38	8	1	1	1
1	16	4	0.0	30	7	1	1	1
1	17	5	0.0	31	8	1	1	1
1	18	6	0.0	28	8	1	1	1
1	19	7	0.0					
1	20	1	0.0					
1	21	2	0.0	66	13	1	1	1
1	22	3	0.0	72	16	1	1	1
1	23	4	0.0	69	15	1	1	1
1	24	5	0.0	69	13	1	1	1
1	25	6	0.0	64	14	1	1	1
1	26	7	0.0					
1	27	1	0.0					
1	28	2	0.0	55	11	1	1	1
1	29	3	0.0	60	12	1	1	1
1	30	4	1.0	55	12	1	1	1
1	31	5	0.0	42	9	1	1	1
2	1	6	0.0	59	12	1	1	1
2	2	7	0.0					
2	3	1	0.0					
2	4	2	0.0	66	11	1	1	1
2	5	3	7.6	81	16	1	1	1
2	6	4	5.1	74	13	1	1	1
2	7	5	0.0	70	14	1	1	1
2	8	6	0.0	38	7	1	1	1
2	9	7	0.0					
2	10	1	5.1					
2	11	2	0.0	56	13	1	1	1
2	12	3	0.0	67	12	1	1	1
2	13	4	0.0	95	18	1	1	1
2	14	5	2.5	81	16	1	1	1
2	15	6	0.0	27	5	1	1	1
2	16	7	0.0					
2	17	1	0.0					
2	18	hol	0.0					
2	19	3	1.3	83	15	1	1	1
2	20	4	0.0	81	15	1	1	1
2	21	5	0.0	92	17	1	1	1
2	22	6	0.0	127	15	1	1	1
2	23	7	0.0					
2	24	1	0.0					
2	25	2	0.0	78	15	1	1	1
2	26	3	0.0	78	16	1	1	1
2	27	4	0.0	106	13	1	1	1
2	28	5	0.0	86	18	1	1	1
3	1	6	3.0	73	16	1	1	1
3	2	7	0.0					
3	3	1	0.0					
3	4	2	2.0	83	16	1	1	1
3	5	3	3.8	82	15	1	1	1

Table D.6. (cont'd).

3	6	4	3.0	82	15	1	1	1
3	7	5	0.0	50	15	1	1	1
3	8	6	0.0	34	8	1	1	1
3	9	7	0.0					
3	10	1	0.0					
3	11	2	0.0	60	13	1	1	1
3	12	3	0.0	62	12	1	1	1
3	13	4	0.0	58	12	1	1	1
3	14	5	0.0	63	15	1	1	1
3	15	6	0.0	54	13	1	1	1
3	16	7	0.0					
3	17	1	0.0					
3	18	2	0.0	66	12	1	1	1
3	19	3	0.0	80	14	1	1	1
3	20	4	0.0	66	14	1	1	1
3	21	5	0.0	80	13	1	1	1
3	22	hol	6.3					
3	23	7	4.6					
3	24	1	0.0					
3	25	2	0.0	75	13	1	1	1
3	26	3	0.0	54	8	1	1	1
3	27	4	49.5	40	8	1	1	1
3	28	hol	0.0					
3	29	hol	0.0					
3	30	7	0.0					
3	31	1	0.0					
4	1	2	0.0	79	15	1	1	1
4	2	3	0.0	79	15	1	1	1
4	3	4	0.0	55	13	1	1	1
4	4	5	0.0	72	14	1	1	1
4	5	6	0.0	16	4	1	1	1
4	6	7	0.0					
4	7	1	0.0					
4	8	2	0.0	40	9	1	1	1
4	9	3	0.0	22	4	1	1	1
4	10	4	0.0	36	6	1	1	1
4	11	5	0.0	38	8	1	1	1
4	12	6	0.0	19	4	1	1	1
4	13	7	0.0					
4	14	1	0.0					
4	15	2	0.0	34	7	1	1	1
4	16	hol	0.0					
4	17	4	0.0	26	6	1	1	1
4	18	5	0.0	19	4	1	1	1
4	19	6	0.0	19	5	1	1	1
4	20	7	0.0					
4	21	1	0.0					
4	22	2	0.0	18	5	1	1	1
4	23	3	0.0	15	4	1	1	1
4	24	4	0.0	13	3	1	1	1
4	25	5	0.0	11	2	1	1	1
4	26	6	0.0	11	2	1	1	1
4	27	7	0.0					
4	28	1	0.0					
4	29	2	0.0	21	4	1	1	1
4	30	3	0.0	21	4	1	1	1
10	1	3	0.0	0	0			*
10	2	4	0.0	0	0			*

Table D.6. (cont'd).

10	3	5	0.0	14	3	1	1	1
10	4	6	0.0	15	3	1	1	1
10	5	7	0.0					
10	6	1	0.0					
10	7	2	0.0	17	5	1	1	1
10	8	3	0.0	13	4	1	1	1
10	9	4	0.0	14	3	1	1	1
10	10	5	10.2	2	1	0	0	0
10	11	6	12.7	2	1	0	0	0
10	12	hol	0.0					
10	13	1	0.0					
10	14	2	0.0	13	2	1	1	1
10	15	3	0.0	17	4	1	1	1
10	16	4	1.3	20	5	1	1	1
10	17	5	0.0	0	0			*
10	18	6	0.0	15	4	1	1	1
10	19	7	0.0					
10	20	1	0.0					
10	21	2	0.0	13	2	1	1	1
10	22	3	0.0	13	3	1	1	1
10	23	4	0.0	14	3	1	1	1
10	24	5	0.0	16	4	1	1	1
10	25	6	0.0	15	3	1	1	1
10	26	7	0.0					
10	27	1	0.0					
10	28	2	0.0	16	4	1	1	1
10	29	3	0.0	23	5	1	1	1
10	30	4	0.0	15	3	1	1	1
10	31	5	0.0	17	3	1	1	1
11	1	6	0.0	0	0			*
11	2	7	0.0					
11	3	1	0.0					
11	4	2	0.0	17	3	1	1	1
11	5	3	0.0	7	1	0	0	0
11	6	4	36.8	15	4	1	1	1
11	7	5	8.9	0	0	0	0	0
11	8	6	14.0	0	0	0	0	0
11	9	7	0.0					
11	10	1	0.0					
11	11	hol	0.0					
11	12	3	0.0	14	3	1	1	1
11	13	4	0.0	13	3	1	1	1
11	14	5	0.0	12	3	1	1	1
11	15	6	0.0	26	5	1	1	1
11	16	7	0.0					
11	17	1	0.0					
11	18	2	0.0	30	5	1	1	1
11	19	hol	0.0					
11	20	4	0.0	23	7	1	1	1
11	21	5	2.5	15	5	1	1	1
11	22	6	0.0	35	6	1	1	1
11	23	7	0.0					
11	24	1	0.0					
11	25	2	0.0	60	13	1	1	1
11	26	3	0.0	23	8	1	1	1
11	27	4	35.6	24	7	1	1	1
11	28	hol	0.0					
11	29	6	0.0	0	0			*
11	30	7	0.0					

Table D.6. (cont'd).

12	1	1	0.0					
12	2	2	0.0	34	7	1	1	1
12	3	3	6.3	34	6	1	1	1
12	4	4	0.0	41	8	1	1	1
12	5	5	0.0	17	4	1	1	1
12	6	6	0.0	28	8	1	1	1
12	7	7	0.0					
12	8	1	0.0					
12	9	2	0.0	44	8	1	1	1
12	10	3	0.0	37	6	1	1	1
12	11	4	0.0	29	5	1	1	1
12	12	5	0.0	32	6	1	1	1
12	13	6	0.0	33	4	1	1	1
12	14	7	0.0					
12	15	1	0.0					
12	16	2	0.0	45	8	1	1	1
12	17	3	0.0	40	8	1	1	1
12	18	4	0.0	37	8	1	1	1
12	19	5	0.0	23	6	1	1	1
12	20	6	0.0	41	7	1	1	1
12	21	7	0.0					
12	22	1	0.0					
12	23	2	0.0	58	8	1	1	1
12	24	3	0.0	16	4	1	1	1
12	25	hol	0.0					
12	26	5	0.0	33	6	1	1	1
12	27	6	0.0	16	5	1	1	1
12	28	7	0.0					
12	29	1	0.0					
12	30	2	0.0	33	6	1	1	1
12	31	3	0.0	20	4	1	1	1
1992								
1	1	hol	0.0					
1	2	5	0.0	35	8	1	1	1
1	3	6	0.0	36	8	1	1	1
1	4	7	0.0					
1	5	1	0.0					
1	6	hol	127.0					
1	7	3	0.0	0	0	0	0	0
1	8	4	0.0	35	7	1	1	1
1	9	5	0.0	32	8	1	1	1
1	10	6	0.0	34	6	1	1	1
1	11	7	0.0					
1	12	1	0.0					
1	13	2	0.0	85	15	1	1	1
1	14	3	0.0	67	15	1	1	1
1	15	4	0.0	27	9	1	1	1
1	16	5	0.0	40	7	1	1	1
1	17	6	0.0	26	7	1	1	1
1	18	7	0.0					
1	19	1	0.0					
1	20	hol	0.0					
1	21	3	0.0	84	17	1	1	1
1	22	4	0.0	45	9	1	1	1
1	23	5	7.6	30	9	1	1	1
1	24	6	0.0	52	10	1	1	1
1	25	7	0.0					
1	26	1	0.0					
1	27	2	0.0	64	14	1	1	1
1	28	3	0.0	63	14	1	1	1

Table D.6. (cont'd).

1	29	4	0.0	18	7	1	1	1
1	30	5	0.0	57	10	1	1	1
1	31	6	0.0	52	10	1	1	1
2	1	7	0.0					
2	2	1	0.0					
2	3	2	0.0	59	12	1	1	1
2	4	3	0.0	62	10	1	1	1
2	5	4	5.1	56	10	1	1	1
2	6	5	0.0	57	13	1	1	1
2	7	6	0.0	27	10	1	1	1
2	8	7	0.0					
2	9	1	2.5					
2	10	2	0.0	62	12	1	1	1
2	11	3	0.0	56	15	1	1	1
2	12	hol	0.0					
2	13	5	0.0	66	14	1	1	1
2	14	6	0.0	61	12	1	1	1
2	15	7	0.0					
2	16	1	0.0					
2	17	2	0.0	48	11	1	1	1
2	18	3	0.0	50	14	1	1	1
2	19	4	0.0	53	12	1	1	1
2	20	5	0.0	49	10	1	1	1
2	21	6	0.0	40	7	1	1	1
2	22	7	0.0					
2	23	1	0.0					
2	24	2	0.0	37	11	1	1	1
2	25	3	7.6	32	13	1	1	1
2	26	4	0.0	41	12	1	1	1
2	27	5	0.0	43	9	1	1	1
2	28	6	0.0	43	9	1	1	1
2	29	7	0.0					

Table D.7. Observed tillage operations performed with crawler tractors data and definition of working days for the Guanica Valley vegetable field locations.

DECISION USED: A NON WORKING DAY IS ANY DAY WITH REPORTED DATA AFFECTED BY RAINFALL AS FOLLOW:

1. AT LEAST ONE OPERATOR PER DAY
2. MORE THAN 4 HOURS PER DAY

DATE			DAY OF THE WEEK [§]	PREC. (mm)	REPORTED DATA AFFECTED BY RAIN		WORKING DAY DECISION		
YEAR	MONTH	DAY			oper./day [§]	h/day	days/day [†]	h/day [§]	W,NW [†]
1990									
	5	1	3	2.5			1	1	1
	5	2	4	11.9			1	1	1
	5	3	5	0.0	1	2	0	1	0
	5	4	6	0.0			1	1	1
	5	5	7	0.0					
	5	6	1	0.0					
	5	7	2	0.0			1	1	1
	5	8	3	0.0			1	1	1
	5	9	4	0.0			1	1	1
	5	10	5	0.0			1	1	1
	5	11	6	0.0			1	1	1
	5	12	7	0.0					
	5	13	1	0.0					
	5	14	2	0.0			1	1	1
	5	15	3	0.0			1	1	1
	5	16	4	0.0			1	1	1
	5	17	5	0.0			1	1	1
	5	18	6	0.0			1	1	1
	5	19	7	0.0					
	5	20	1	0.0					
	5	21	2	0.0			1	1	1
	5	22	3	0.0			1	1	1
	5	23	4	0.0			1	1	1
	5	24	5	0.0			1	1	1
	5	25	6	0.0			1	1	1
	5	26	7	0.0					
	5	27	1	0.0					
	5	28	hol*	0.0					
	5	29	3	0.0			1	1	1
	5	30	4	0.0			1	1	1
	5	31	5	0.0			1	1	1

§ - 1 = Sunday, 2 = Monday, 3 = Tuesday, etc.

§ - Number of operators that reported a full day as a non-working day

† - Working or non-working day base on total number of operators that reported a full day affected by rainfall (1 or 0 respectively).

§ - Working or non-working day base on total number of reported hours per day affected by rainfall (1 or 0 respectively).

† - Final decision for the day: W = Working day, NW = Non working day (1 and 0 respectively).

* - Holiday

Table D.7. (cont'd).

6	1	6	0.0			1	1	1
6	2	7	0.0					
6	3	1	0.0					
6	4	2	0.0			1	1	1
6	5	3	0.0			1	1	1
6	6	4	0.0			1	1	1
6	7	5	1.8			1	1	1
6	8	6	0.0			1	1	1
6	9	7	0.0					
6	10	1	0.0					
6	11	2	0.0			1	1	1
6	12	3	2.5			1	1	1
6	13	4	0.0			1	1	1
6	14	5	114.3	2	3	0	1	0
6	15	6	11.9			1	1	1
6	16	7	0.0					
6	17	1	0.0					
6	18	2	3.8		7	1	0	0
6	19	3	0.0			1	1	1
6	20	4	0.0			1	1	1
6	21	5	0.0			1	1	1
6	22	6	0.0			1	1	1
6	23	7	0.0					
6	24	1	0.0					
6	25	2	0.0			1	1	1
6	26	3	0.0			1	1	1
6	27	4	0.0			1	1	1
6	28	5	0.0			1	1	1
6	29	6	0.0			1	1	1
6	30	7	0.0					
7	1	1	0.0					
7	2	2	0.0			1	1	1
7	3	3	0.0			1	1	1
7	4	hol	0.0					
7	5	5	0.0			1	1	1
7	6	6	0.0			1	1	1
7	7	7	0.0					
7	8	1	0.0					
7	9	2	0.0			1	1	1
7	10	3	0.0			1	1	1
7	11	4	0.0			1	1	1
7	12	5	0.0			1	1	1
7	13	6	0.0			1	1	1
7	14	7	0.0					
7	15	1	76.2					
7	16	2	8.1	2	4	0	0	0
7	17	hol	3.8					
7	18	4	0.0	2	7	0	0	0
7	19	5	0.0			1	1	1
7	20	6	0.0			1	1	1
7	21	7	0.0					
7	22	1	12.4					
7	23	2	0.0			1	1	1
7	24	3	0.0			1	1	1
7	25	hol	0.0					
7	26	5	12.2			1	1	1
7	27	6	12.7	1		0	1	0
7	28	7	0.0					
7	29	1	0.0					

Table D.7. (cont'd).

7	30	2	0.0			1	1	1
7	31	3	0.0			1	1	1
						1	1	1
8	1	4	1.8			1	1	1
8	2	5	0.0			1	1	1
8	3	6	0.0			1	1	1
8	4	7	23.9					
8	5	1	0.0					
8	6	2	0.0			1	1	1
8	7	3	0.0			1	1	1
8	8	4	0.0			1	1	1
8	9	5	0.0			1	1	1
8	10	6	0.0			1	1	1
8	11	7	0.0					
8	12	1	0.0					
8	13	2	0.0			1	1	1
8	14	3	0.0			1	1	1
8	15	4	0.0			1	1	1
8	16	5	0.0			1	1	1
8	17	6	0.0			1	1	1
8	18	7	0.0					
8	19	1	0.0					
8	20	2	0.0			1	1	1
8	21	3	0.0			1	1	1
8	22	4	0.0			1	1	1
8	23	5	0.0			1	1	1
8	24	6	0.0			1	1	1
8	25	7	0.0					
8	26	1	0.0					
8	27	2	0.0			1	1	1
8	28	3	0.0			1	1	1
8	29	4	36.8	5		1	0	0
8	30	5	0.0			1	1	1
8	31	6	0.0			1	1	1
9	1	7	0.0					
9	2	1	25.4					
9	3	hol	0.0					
9	4	3	0.0			1	1	1
9	5	4	0.0			1	1	1
9	6	5	0.0			1	1	1
9	7	6	0.0			1	1	1
9	8	7	0.0					
9	9	1	11.2					
9	10	2	0.0			1	1	1
9	11	3	0.0			1	1	1
9	12	4	0.0			1	1	1
9	13	5	0.0			1	1	1
9	14	6	0.0			1	1	1
9	15	7	0.0					
9	16	1	37.1					
9	17	2	0.0			1	1	1
9	18	3	0.0			1	1	1
9	19	4	0.0			1	1	1
9	20	5	0.0			1	1	1
9	21	6	0.0			1	1	1
9	22	7	0.0					
9	23	1	0.0					
9	24	2	7.6			1	1	1
9	25	3	76.2	1		0	1	0

Table D.7. (cont'd).

1991	9	26	4	24.1	2		0	1	0
	9	27	5	0.0	1	3	0	1	0
	9	28	6	10.9			1	1	1
	9	29	7	0.0					
	9	30	1	0.0					
	5	1	4	0.0			1	1	1
	5	2	5	0.0			1	1	1
	5	3	6	0.0			1	1	1
	5	4	7	0.0					
	5	5	1	0.0					
	5	6	2	0.0			1	1	1
	5	7	3	0.0			1	1	1
	5	8	4	16.5	1	8	0	0	0
	5	9	5	0.0		2	1	1	1
	5	10	6	0.0			1	1	1
	5	11	7	8.9					
	5	12	1	0.0					
	5	13	2	0.0			1	1	1
	5	14	3	0.0			1	1	1
	5	15	4	0.0			1	1	1
	5	16	5	0.0			1	1	1
	5	17	6	0.0			1	1	1
	5	18	7	6.3					
	5	19	1	3.8					
	5	20	2	0.0			1	1	1
	5	21	3	0.0			1	1	1
	5	22	4	0.0			1	1	1
	5	23	5	0.0			1	1	1
	5	24	6	0.0			1	1	1
	5	25	7	24.1					
	5	26	1	0.0					
	5	27	hol	0.0					
	5	28	3	0.0			1	1	1
	5	29	4	0.0			1	1	1
	5	30	5	0.0			1	1	1
	5	31	6	0.0			1	1	1
	6	1	7	0.0					
	6	2	1	0.0					
	6	3	2	0.0			1	1	1
	6	4	3	1.3			1	1	1
	6	5	4	0.0			1	1	1
	6	6	5	1.0			1	1	1
	6	7	6	0.0			1	1	1
	6	8	7	0.0					
	6	9	1	0.0					
	6	10	2	0.0			1	1	1
	6	11	3	4.8			1	1	1
	6	12	4	0.0			1	1	1
	6	13	5	0.0			1	1	1
	6	14	6	0.0			1	1	1
	6	15	7	0.0					
	6	16	1	0.0					
	6	17	2	0.0			1	1	1
	6	18	3	0.0			1	1	1
	6	19	4	0.0			1	1	1
	6	20	5	0.0			1	1	1
	6	21	6	0.0			1	1	1
	6	22	7	0.0					

Table D.7. (cont'd).

6	23	1	0.0					
6	24	2	0.0			1	1	1
6	25	3	0.0			1	1	1
6	26	4	0.0			1	1	1
6	27	5	0.0			1	1	1
6	28	6	0.0			1	1	1
6	29	7	0.0					
6	30	1	0.0					
7	1	2	0.0			1	1	1
7	2	3	0.0			1	1	1
7	3	4	0.0		3	1	1	1
7	4	hol	10.2					
7	5	6	0.0			1	1	1
7	6	7	0.0					
7	7	1	0.0					
7	8	2	0.0			1	1	1
7	9	3	0.0			1	1	1
7	10	4	0.0			1	1	1
7	11	5	0.0			1	1	1
7	12	6	0.0			1	1	1
7	13	7	0.0					
7	14	1	0.0					
7	15	2	34.3			1	1	1
7	16	3	0.0	2		0	1	0
7	17	hol	0.0		2	1	1	1
7	18	5	0.0			1	1	1
7	19	6	0.0			1	1	1
7	20	7	0.0					
7	21	1	0.0					
7	22	2	5.6			1	1	1
7	23	3	0.0			1	1	1
7	24	4	0.0			1	1	1
7	25	hol	0.0					
7	26	6	0.0			1	1	1
7	27	7	0.0					
7	28	1	5.1					
7	29	2	0.0			1	1	1
7	30	3	0.0			1	1	1
7	31	4	0.0			1	1	1
8	1	5	0.0			1	1	1
8	2	6	0.0			1	1	1
8	3	7	0.0					
8	4	1	24.4					
8	5	2	0.0			1	1	1
8	6	3	0.0			1	1	1
8	7	4	0.0			1	1	1
8	8	5	0.0			1	1	1
8	9	6	0.0			1	1	1
8	10	7	0.0					
8	11	1	0.0					
8	12	2	0.0			1	1	1
8	13	3	0.0			1	1	1
8	14	4	0.0			1	1	1
8	15	5	0.0			1	1	1
8	16	6	0.0			1	1	1
8	17	7	0.0					
8	18	1	0.0					
8	19	2	0.0			1	1	1

Table D.7. (cont'd).

8	20	3	0.0			1	1	1
8	21	4	0.0			1	1	1
8	22	5	50.8	2	5	0	0	0
8	23	6	0.0		2	1	1	1
8	24	7	0.0					
8	25	1	0.0					
8	26	2	0.0			1	1	1
8	27	3	2.3			1	1	1
8	28	4	5.1			1	1	1
8	29	5	0.0			1	1	1
8	30	6	0.0			1	1	1
8	31	7	0.0					
9	1	1	0.0					
9	2	hol	0.0					
9	3	3	0.0			1	1	1
9	4	4	0.0			1	1	1
9	5	5	0.0			1	1	1
9	6	6	0.0			1	1	1
9	7	7	0.0					
9	8	1	8.9					
9	9	2	0.0			1	1	1
9	10	3	0.0			1	1	1
9	11	4	0.0			1	1	1
9	12	5	0.0			1	1	1
9	13	6	0.0			1	1	1
9	14	7	0.0					
9	15	1	23.9					
9	16	2	0.0			1	1	1
9	17	3	28.4	2		0	1	0
9	18	4	0.0	1	8	0	0	0
9	19	5	0.0			1	1	1
9	20	6	0.0			1	1	1
9	21	7	0.0					
9	22	1	0.0					
9	23	2	3.0			1	1	1
9	24	3	0.0			1	1	1
9	25	4	0.0			1	1	1
9	26	5	0.0			1	1	1
9	27	6	0.0			1	1	1
9	28	7	0.0					
9	29	1	0.0					
9	30	2	0.0			1	1	1

APPENDIX E

APPENDIX E: Soil moisture samples data.

Soil moisture measurements collected during the summer of 1992 in the south coast of Puerto Rico are presented in Tables E.1 to E.3.

Table E.1. Soil moisture content (SMC) samples for San Anton silty clay seeded with pumpkins.

Date	Prec.	Soil Depth	SMC %	SMC % Layer Mean	SMC % 150 mm Depth Mean
	(mm)	(mm)		(kg kg ⁻¹)	
8/5/92	7.1	0-150	19.16		
		0-150	18.93		
		0-150	17.76	18.61	18.61
8/6/92	25.9	0-50	18.29		
		0-50	16.75		
		0-50	14.17	16.40	
		50-100	19.81		
		50-100	16.22		
		50-100	22.16	19.40	
		100-150	22.22		
		100-150	22.17		
		100-150	30.43	24.94	20.24
8/7/92	0.0	0-50	21.43		
		0-50	18.10		
		0-50	19.70	19.74	
		50-100	24.15		
		50-100	20.20		
		50-100	23.00	22.45	
		100-150	21.74		
		100-150	21.96		
		100-150	25.00	22.90	21.69
8/8/92	0.0	0-50	17.92		
		0-50	15.21		
		0-50	18.50	17.21	
		50-100	16.26		
		50-100	20.98		
		50-100	20.98	19.40	
		100-150	16.28		
		100-150	26.26		
		100-150	25.00	22.51	19.70

Table E.2. Soil moisture content (SMC) samples for Santa Isabel clay with plastic mulch and no crop.

Date	Prec.	Soil Depth	SMC %	SMC % Layer Mean	SMC % 150 mm Depth Mean
	(mm)	(mm)		(kg kg ⁻¹)	
8/5/92	7.1	0-150	29.10		
		0-150	26.30		
		0-150	25.94	27.11	27.11
8/6/92	25.9	0-50	26.41		
		0-50	16.57		
		0-50	25.00	22.63	
		50-100	37.31		
		50-100	17.07		
		50-100	27.75	27.38	
		100-150	27.50		
		100-150	28.64		
		100-150	24.34	26.83	25.61
8/7/92	0.0	0-50	16.92		
		0-50	18.48		
		0-50	20.51	18.64	
		50-100	26.67		
		50-100	22.73		
		50-100	24.77	24.72	
		100-150	24.50		
		100-150	24.40		
		100-150	21.72	23.54	22.30
8/8/92	0.0	0-50	17.14		
		0-50	17.95		
		0-50	17.56	17.55	
		50-100	25.67		
		50-100	26.56		
		50-100	25.64	25.96	
		100-150	28.50		
		100-150	29.15		
		100-150	31.31	29.65	24.38

Table E.3. Soil moisture content (SMC) samples for Santa Isabel clay in bare condition.

Date	Prec.	Soil Depth	SMC %	SMC % Layer Mean	SMC % 150 mm Depth Mean
	(mm)	(mm)		(kg kg ⁻¹)	
8/5/92	7.1	0-150	20.15		
		0-150	18.69		
		0-150	24.36	21.06	21.06
8/6/92	25.9	0-50	26.41		
		0-50	21.91		
		0-50	23.12	23.81	
		50-100	24.11		
		50-100	24.88		
		50-100	28.04	25.68	
		100-150	24.06		
		100-150	25.68		
		100-150	28.06	25.93	25.14
8/7/92	0.0	0-50	21.67		
		0-50	16.57		
		0-50	21.38	19.88	
		50-100	27.00		
		50-100	22.50		
		50-100	22.44	23.98	
		100-150	24.74		
		100-150	25.00		
		100-150	22.35	24.03	22.63
8/8/92	0.0	0-50	20.43		
		0-50	21.53		
		0-50	21.59	21.18	
		50-100	23.44		
		50-100	23.92		
		50-100	24.40	23.92	
		100-150	26.83		
		100-150	26.87		
		100-150	26.83	26.84	23.98

MICHIGAN STATE UNIV. LIBRARIES



31293008927398