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ECONOMIC VALUATION OF ENVIRONMENTAL QUALITY ASPECTS OF UPLAND AGRICULTURAL PROJECTS IN KOREA: A CASE STUDY*

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Background Information

Korea is a rapidly urbanizing country with a growing population and increasing needs for food. To meet its food needs Korea is putting more and more upland areas into agricultural production. As relatively flat farm land is lost to urban growth and industrial development, the development of hilly upland areas is seen as a major option for future expansion of agricultural production.

In this case study, "uplands" refers to all cultivated uplands other than terraced rice paddy fields; most of these uplands are located on hillsides. Uncultivated uplands are classfied as "forest" lands (even though some of these lands are only marginally forested). About two-thirds of the total land area in Korea is classified as forest lands (see Table 1).

TABLE 1 LAND USE IN KOREA, 1980

	Arable Land					
	Paddyrice	Upland	Total	Forest	Others	Total
Area('000 ha)	1,290	948	2,238	6,613	1,028	9,880
Percent of Total Area (%)	13.1	9.6	22.7	66.9	10.4	100.0

—Arable land per capital: 0.06 ha
—Forest land per capital: 0.18 ha
Source: Ministry of Agriculture, 1981

Total cultivated agricultural area is about 2.2 million hectares in Korea and the nonrice-paddy field uplands account for about 40 percent of this total. There are about 2.1 million farm families and each farm is

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slightly larger than 1 hectare. Korea's population is over 38 million people and, since domestic production is insufficient to meet domestic demand, about 2 billion dollars worth of food is imported each year.

In the 1970–1978 period Korea's growth rate of population was 2 percent per year and real GNP per capita grew at 8.1 percent per year. In order to meet the rapidly increasing demand for food and other agricultural products and to compensate for farmland lost to urban and industrial development (Table 2), the government has embarked on an ambitious program for upland development. The ultimate potential for further upland development of land with a slope of less than 30 percent has been estimated by the Agricultural Development Corporation as 516 thousand hectares, divided among 2,400 parcels. Of this area less than 30 percent has a slope of less than 15 percent.

TABLE 2 AMOUNT OF ARABLE LAND CONVERTED TO NON-AGRICULTURAL USES, 1966–1981, KOREA

	1966–69	1971–73	1976	1977	1978–81
Converted Area (ha)	46,000	72,000	10,000	14,000	51,6000*

* Estimate based on the 1966–1977 rate of decrease in arable land of 12,900 ha per year.

Source: MAF, 1982.

Environmental Dimensions

In the past the performance of upland development areas has not been entirely satisfactory, mainly due to poor design and construction coupled with the inadequate soil management techniques used in cultivation. This resulted in heavy soil erosion and deterioration of the existing natural systems. Soil erosion and downstream deposition of silt have created serious damage to the environment as well as antagonism from paddy-growers. Some areas reclaimed by private initiative were abandoned as productivity fell due to the low level of fertility and moisture retaining capacity.

As a result, both policy-makers and farmers have had increasing doubts about the effects of upland development. Despite the need to expand the agricultural production base of Korea, the government seems ready to reduce its strong commitment to upland development.

In the past, little emphasis was given to environmental aspects in planning for and evaluating upland reclamation projects. Conventional benefit-cost analysis techniques were used and only such positive products as increased production of food grains and fresh produce were included as benefits. Environmental factors such as soil erosion, water run-off, and siltation effects on downhill streams, rivers and paddy lands were ignored. Therefore, a comprehensive re-evaluation of upland agricultural projects is required to evaluate these environmental dimensions properly.

In this context, economic valuations of environmental effects of various soil management techniques are presented. These analyses are based on physical data obtained by the Office of Rural Development Soil Science Research Team in Icheon and Gochang where net areas of 272 and 325 hectares of hillside lands were initially developed in 1974 (Figure A-1).

These areas are hilly uplands with an average slope of 15 percent and red-yellow sandy loam soils. The fields were planted twice a year with one soybean and one barley crop. By use of a Lysimeter, soil and nutrient loss rates were measured with the soybean barley cropping system under nine different types of soil treatments. The test plots were 10 meters long by 2 meters wide and had a 15 percent slope.

Since the main environmental problems were rapid water runoff (causing soil erosion) and lack of deep percolation of rainwater into the fields, the soil management techniques were designed to slow runoff and increase water infiltration. The soil management techniques used included various forms of trenching, chiseling, mulching, and vertical mulching. The reduction in soil erosion between the control (check) plot and the other treatments is presented in Table 3. Annual soil losses were reduced by up to 90 percent in some cases.

The different soil treatments used are defined in Table 4 and their annual costs are presented in Table 5.

TABLE 3 SOIL LOSS IN UPLAND AREAS—A COMPARISON OF EXISTING PRACTICES AND NEW MANAGEMENT TECHNIQUES, 1976–1977

(kg/0.1 ha)

Year	Crop	Existing Practices (Control Plot)	New Management Techniques: Grass Band	Chisel-ing	Trench-ing	Verti-Mulching	Mulch-ing	Mulch + Chisel	Mulch + Trench	Mulch + Vertical Mulch
1976	Soybean	4,275	1,802	2,217	2,092	1,269	940	707	542	512
	Barley	432	52	188	212	100	70	70	58	52
	Annual total	4,707	1,854	2,405	2,304	1,369	1,010	777	600	564
1977	Soybean	3,116	689	1,276	2,062	1,961	227	235	310	149
	Barley	246	20	184	211	221	3	3	0.3	1
	Annual total	3,362	709	1,460	2,273	2,182	230	238	310.3	150
Annual Average		4,035	1,282	1,933	2,289	1,776	621	508	455	357
Index		100.0	31.8	47.9	56.7	44.0	15.4	12.6	11.3	8.9

Note: 1 *Are* (a) = 100m²; 1 hectare = 100 *Are*(a).

Source: J.N. Im, *et al.*, Studies on Soil Erosion Control in Newly Reclaimed Upland Soil, ORD, 1978–80 and their on-going experiment data.

The Problem

In order to evaluate the trade-offs involved between the various improved agricultural practices, a Replacement-Cost Approach analysis will be used. This technique is briefly mentioned in Chapter 7 of the *Guide*.[1]

The *Replacement-Cost Approach* is based on the premise that the costs of replacing productive assets that have been damaged because of pollution or improper on-site management can be measured. These costs are taken as a minimum estimate of the value of measures which will reduce pollution or improve on-site management practices.

In this case study the productive asset that has been damaged is the soil in the upland areas. Leaching of nutrients and soil erosion have both occurred and have reduced the value of the land by reducing its productivity. The cost of physically replacing lost soil and restoring lost nutrients is measured (the replacement cost); this cost is then used as the *minimum benefit* or *value* from steps taken to prevent these environmental problems. When the proposed preventive steps cost less than the replacement costs, the preventive measures are economically justified. The assumption is that these replacement costs are not greater than the value of the productive resources destroyed—that is, that the replacement is worth doing. Because of a development project, one way to calculate the value of that resource lost is to estimate the cost of another project that would replace the forgone resource. This "shadow-project" is then used as a surrogate for the value of the threatened environmental service (a service that may be difficult to value). For example, if some lake shore land in a rural area is presently used for outdoor recreation but is required for an industrial development, a shadow-project evaluation would examine the cost of creating a similar lake and surroundings in another area. In the Korean example, a shadow project is not considered. Rather, detailed estimates of the costs of physically replacing productive assets (soil and nutrients) are made.

The Data

In the case study two types of physical losses are considered—soil and nutrients. While these two losses frequently occurred simultaneously (heavy rains leading to soil erosion and water runoff), in this analysis they are considered as separate elements.

Soil Loss: The two sample survey areas (Inchon and Gochang) were measured for soil loss by the Research Bureau of the Office of Rural Develop-

[1] *Environment, Natural Systems and Development: an Economic Valuation Guide* by M.M. Hufschmidt, D.E. James, A.D. Meister, B.T. Bower and J.A. Dixon, forthcoming, Johns Hopkins University Press, early 1983.

ment. They found average annual soil losses of 40.35 tons per hectare, close to the theoretical loss of 39.9 tons per hectare estimated from the Universal Soil Loss Equation (see Annex 1). The environmental effects of this erosion are considered later.

Nutrient Loss: Average annual nutrient loss per hectare was calculated by use of a Lysimeter on trial plots. The losses were as follows:

Nutrient	*Rate of Loss (kg/ha)*
N	15.7
P	3.6
K	14.6
Ca	10.6
Mg	1.6
Organic Matter (O.M.)	75.4

Water Runoff: During the two year observation period average annual runoff per hectare was 1,380 tons, or equivalent to roughly 1,380 mm of rainfall. While average rainfall in Korea is about 1,200 mm per year (see Annex Table A-1 and Annex Figure A-1), the sample areas had heavier rainfall than the average. A very high percent of total rainfall was lost in runoff. The runoff caused the soil erosion and nutrient leaching.

The Economic Analysis

The analysis evaluates the environmental costs associated with present upland management practices and the benefits and costs of alternative soil management techniques. Soil erosion has resulted in siltation of downstream paddy fields, especially in the first two years after estabilishing the upland area. To counteract this erosion, a number of treatments have been devised to stabilize the soil (Tables 4, 5).

Table 3 shows the soil loss associated with soybean and barley production in upland areas under conventional and various proposed management practices. The type of crop grown, as well as rainfall quantity and timing, affect the soil loss rates. With conventional practices, soil losses are high: over 40 tons per hectare. The use of new management techniques causes a dramatic drop in the erosion rates, especially when combined with the application of mulch.

Tables 6 and 7 show nutrient loss levels and water runoffs associated with the proposed new management practices.

Two concepts are considered in this case:

1) The cost of replacing the lost nutrients and soil in the upland areas and cleaning up the silted paddy fields downstream (the Replacement Cost).

TABLE 4 DEFINITIONS OF SOIL TREATMENT TECHNIQUE

1. Control plots of conventional soil management practice —Topsoil is ploughed to a depth of 20 centimeters for the first crop of the year; it is also limed and fused-phosophate is applied at a rate equivalent to 5 percent phosphorous.
2. Grass band— Weeping love grass is planted in bands 20 centimeters wide with 2 meters intervals.
3. Chiseling*——The soil surface is broken to a depth of 60 centimeters and a width of one meter by using tractor-attached bullet-headed driller. The bands are 2 meters apart.
4. Trenching*——A line of trenches is dug, 80 centimeters deep with a width of 20 centimeters, at 2 meters intervals. The trenches are filled in with loose soil.
5. Vertical mulching* —Trenches are dug as above but filled in part with rice-straw. The topsoil is treated as in the control plot.
6. Mulching——The surface is covered with rice-straws at a rate of 300 kg/10 *Are* after every seed-sowing.

* The so-called "subsoiling technique" include chieslling, trenching, and vertical mulching.
1 ha·=100 *Are*.

TABLE 5=COSTS OF THE VARIOUS UPLAND SOIL MANAGEMENT TECHNIQUES (WON PER HECTARE: US $1.00 = Won 690; AND ONE MAN-DAY FARM WAGE = Won 5,000)

1. Control plot of conventional practices (incurred annually) (tiller ploughing + lime and phosphorous application)	W 35,000
2. Establishing grass bands (once every 3 years) (weeping love grass + 5 man-days labor)	W 125,000
3. Chiseling (once every 2 years) (tractor hire + 2 man-days labor)	W 110,000
4. Trenching (once every 2 years) (tractor hire + 4 man-days labor)	W 120,000
5. Vertical muching (once every 4 years) (tractor hire + rice straw + 2 man-days labor lime and phosphorous application)	W 185,000 (1st yr) W 85,000 (year 5, 9, 13…)
6. Mulching (annual cost) (rice straw + 2 man-days labor)	W 90,000

2) The costs associated with the various new management practices. The use of these practices will reduce soil erosion and nutrient loss; the costs of implementing these practices and thereby reducing erosion need to be compared to the benefits of these actions, namely, the replacement costs foregone.

In this example only one new management technique is considered, that of combined straw mulching and vertical mulching. This combination gave the best results in physically controlling soil erosion (see Tables 3, 6, and 7).

In order to evaluate the two approaches, additional information is needed. The cost to recover and replace eroded soil in the upland fields is composed of truck rental and spreading costs. These charges are divi-

TABLE 6 LOSS OF NUTRIENT

(kg/0.1 ha/year)

Com-ponents	Existing Practice (Control Plot)	New Management Technique							
		Grass Band	Chisel-ing	Trench-ing	Vertical Mulch	Mulch-ing	Mulch + Chisel	Mulch + Trench	Mulch + Ver. Mulch
Total N	1.572	0.643	1.132	1.141	0.869	0.634	0.485	0.404	0.494
P	0.358	0.041	0.187	0.121	0.080	0.033	0.014	0.010	0.013
K	1.459	0.700	1.120	1.193	0.922	0.689	0.544	0.454	0.556
Ca	1.061	0.296	0.670	0.587	0.432	0.283	0.201	0.165	0.203
Mg	0.162	0.039	0.105	0.096	0.072	0.049	0.036	0.029	0.036
Organic matter	7.535	0.874	3.931	2.512	1.638	0.655	0.328	0.218	0.223

Source: J.N. Im, *et al., ibid.*

TABLE 7 AMOUNT OF RUN-OFF

(ton/0.1 ha/year)

Year	Existing Practice (Control Plot)	New Management Technique							
		Grass Band	Chisel-ing	Trench-ing	Vertical Mulch	Mulch-ing	Mulch + Chisel	Mulch + Trench	Mulch + Ver. Mulch
1976	121.90	42.40	60.90	73.60	26.90	34.60	7.80	9.30	7.60
1977	153.92	67.76	87.78	102.31	66.22	26.31	28.92	19.22	19.91
Average	137.91	55.08	74.34	87.97	46.56	30.46	18.36	14.26	13.76
Index	100.0	39.9	53.9	63.8	33.8	22.1	13.3	10.3	10.0

Source: Same as above.

sible and average won 2000 per ton of soil. The 1980 market values of nutrients (on an elemental basis) are given in Table 8. Labor costs for spreading nutrients and other materials average won 40 per kg spread.

Soil and nutrient replacement are yearly phenomena. In addition, there are costs associated with implementing the new management technique as well as with the continued use of the conventional practice. The new technique, mulch plus vertical mulching, requires that appropriate measures be taken every 4 years. In the first year (year 1), the cost of verti-

TABLE 8. MARKET VALUES OF NUTRIENTS, 1980

	(won/kg)
N	480
P	345
K	105
Ca	60
Mg	1,400
Organic Matter	175

1 US $ = won 690

cal mulching is high: won 185,000 per hectare; in succeeding periods (years 5, 9, 13, etc.) the cost is reduced to won 85,000 per hectare since less labor and materials are required. In addition, there is a yearly expense for mulch of won 90,000 per hectare.

The conventional system only requires a recurring, annual expenditure of won 35,000 for field maintenance and repair. However, the continuing erosion leads to down-stream siltation of paddy fields. This siltation creates damage and leads to decreased productivity; this loss is estimated at won 30,000 per year (60 liters of rice per ha.). A transfer payment is made from the upland to the lowland farmers to cover these losses.

A final cost under the conventional system is for supplemental irrigation. Assume that one-third of the annual runoff has to be replaced by commercial irrigation at an average cost of won 200 per ton of water. No irrigation is required under improved soil management practices.

Results

A Present Value of Net Benefits calculation was done comparing the two chosen alternatives: the present coventional practice and the new management technique of mulch plus vertical mulching. The analysis covered 15 years and used a 10 percent discount rate (for sensitivity analysis purposes other discount rates, for example, 15 and 20 percent, could also be used). Table 9 has details on crop yields for the different options and Table 10 lists 1980 prices for agricultural products in Korea. It is assumed that actual labor requirements for cultivation are the same under both options.

TABLE 9 CROP YIELDS FOR DIFFERENT SOIL MANAGEMENT TECHNIQUES

(Non-irrigated uplands, kg per 0.1 ha)

Treatments	Control Plot	Grass-band	Chiesling	Trenching	Vertical Mulching	Mulching	Mulch + Chisel	Mulch + Trench	Mulch + Ver. Mulch
Soybean	181	201	228	221	223	218	243	238	235
Barley	225	244	282	306	282	277	334	316	322

Source: ORD, 1981.

The present practices were evaluated first. This calculation gives the cost used in the Replacement Cost Approach, that is, how much it costs each year to replace lost soil and nutrients and maintain a given level of production. Based on the information given previously, these costs have 5 main components:

TABLE 10 AGRICULTURAL PRICES RECEIVED BY FARMERS, 1980

Rice (won/100 *l*)	49,312
Barley (won/100 *l*)	23,224
Corn (won/100 *l*)	13,145
(Hulled) Peanut (won/100 *l*)	105,782
Soybean (won/100 *l*)	39,097
Sweet potato (won/3.75 kg)	491
Radish (won/3.75 kg)	269
Red pepper (won/0.6 kg)	2,730
Apple (won/18.75 kg)	5,043
Pear (won/18.75 kg)	5,039

Note: For rice, 100 *l* = 80 kg.
For all other crops, 100 *l* = 75 kg.
Source: NACF, Agricultural Cooperative Monthly Review, 1981

1. Field maintainance and repair	won	35,000
2. Compensation payments		30,000
3. Irrigation costs		92,000
4. Soil replacement		80,700
5. Nutrient replacement—materials		26,404
—labor		4,859
Total cost per hectare	won	268,963

This total cost, won 268,963, is an annual, recurring cost to maintain agricultural production and repair damages caused by soil erosion. The present value of these costs over 15 years at a 10 percent discount rate is won 2,045,754.

The new management technique, vertical mulching plus mulching, has a different stream of costs associated with it. In a straight cost-comparison, the present value of these costs over 15 years will be compared to those under the conventional practice. The fact that yields may even increase with the new technique (Table 9) is considered later.

The costs of the new technique are similar to those in the conventional approach for some items such as compensation, soil replacement and nutrient replacement. The amounts involved are much smaller, however, because of the very substantial decrease in soil erosion under the new management technique. There are no irrigation or field maintainance and repair costs but there are substantial land preparation and mulching costs:

1. Compensation payments	won	2,654
2. Soil replacement		7,140
3. Nutrient replacement —materials		4,016
—labor		610
Total recurring yearly costs	won	14,420

4. Land preparation	—year 1	won	185,000
	year 5, 9, 13		85,000
5. Mulch costs (annual)			90,000

The cost stream varies from year to year with the largest cost occurring in year 1 with periodic jumps in years 5, 9, and 13 when chiseling is redone. In other years the annual cost is only won 104,420. The present value of these costs over 15 years at a 10 percent discount rate is won 1,074,249, or slightly more than half of the cost of the conventional technique. If the benefits from increased barley and soybean yields are added (see Tables 9 and 10) the attractiveness of the new approach increases. The value of increased yields is over won 580,000 per year.

This discussion will end here. It appears that the new soil management technique would be attractive even if yields were the same under both approaches (and even more attractive if the higher yield estimates are accurate). There may be some reasons why all farmers have not adopted the new technique. Possible reasons are listed here with indications of the types of data needed to answer the questions and suggestions for future research in this area.

1. Has the proper discount rate been used? Sensitivity analysis will illustrate how the results will change with higher and lower discount rates.
2. Are the costs charged to the conventional system actually cash costs that are paid by farmers? If compensations, soil replacement and irrigation are excluded, the yearly cost decreases over won 200,000 per hectare, a 75 percent reduction. This change would make the conventional system less expensive than the new technique.
3. The new technique may require large cash expenditures for mulch plus vertical mulching. Is credit a constraint?
4. Will yields actually increase as indicated in Table 9? What can be realistically expected in farmers' fields?

Other questions can and should be asked to fully understand the implications and constraints of the proposed change. This example has shown how environmental aspects of an upland development program have been incorporated in an economic analysis. The Replacement Cost Approach was used to determine the costs involved with an existing system and then compare these costs to those of a proposed alternative soil manament technique. The fact that the new system appears very attractive economically from the social view may not assure its acceptance by farmers, however. The farmers must see it as attractive in terms of their own perceptions of costs. These costs include cash outlays, in kind contributions, and the timing of costs and benefits. If the social and private (farmer) perspective vary, appropriate incentives may be required to secure adoption of the new system.

ANNEX 1

The Universal Soil Loss Equation (USLE) relates a number of variables in predicting annual soil loss from any given piece of land.

The generalized form of the equation is:

$$A = R \times K \times LS \times C \times P$$

where: A = annual soil loss in tons per hectare
R = rainfall factor
K = soil erodibility factor
LS = length and slope factor
C = cropping factor
P = erosion control practice factor

In Icheon, one of the two sample areas, the variables had the following values:
R = 500
K = 0.25 for the sandy loam of Icheon
LS = 1.2 (average slope of 15)
C = 0.35 for barley-soybean mix
P = 0.76 for contoured terraces

Therefore, $A = 500 \times 0.25 \times 1.2 \times 0.35 \times 0.76 \times 39.9$ tons/ha/yr.

Standard reference works on soils explain how the USLE was developed and the ranges of values for the different parameters. See also the discussion in Chapter V in the *Guide*.

ANNEX TABLES

TABLE A-1 RAINFALL DISTRIBUTION BY REGION

(Unit: mm)

Region	January-May	June-August	September-December	Annual
Seoul	248 (19.7%)	752 (59.7%)	260 (20.6%)	1,260 (100.0%)
Daejeon	257	669	238	1,164
Kwangju	309	593	321	1,223
Average	271 (22.3%)	671 (55.2%)	273 (22.5%)	1,215 (100.0%)

TABLE A-2 LENGTH AND SLOPE FACTORS (LS) BY SLOPE AND SLOPE LENGTH

	Slope Length		
Slope	10m	20m	30m
10%	16.0	34.3	58.9
20	55.3	84.1	112.4
30	115.3	147.3	198.0

TABLE A-3 SOIL ERODIBITY FACTORS (K) BY SOIL TYPE

Soil	Sand	Sand Loam	Loam	Clay Loam	Clay
K Value	0.1	0.25	0.29	0.32	0.42

TABLE A-4 CROP FACTORS (C) BY CROPPING PATTERN*

Cropping Pattern	Naked Land	Corn	Soybean	Corn Soybean	Barley Soybean	Upland Paddy	Sweet Potato	Fodder Crops
C Value	1.00	0.52	0.24	0.42	0.35	0.31	0.19	0.01

* Barley is awinter crop, whereas all the other crops listed are summer crops except fodder crops which can be grown in both seasons in Korea.

TABLE A-5 EROSION CONTROL PRACTICE FACTORS (P) BY MANAGEMENT TECHNIQUE

Treatments	Up and Down Cultivation	Contour Farming	Soil Profile Modification	Grass Band	Mulching	Mulching and Ver. Mulch
P Value	1.00	0.76	0.45	0.16	0.05	0.04

FIGUREA-1 RAINFALL FACTOR (R) MAP OF KOREA

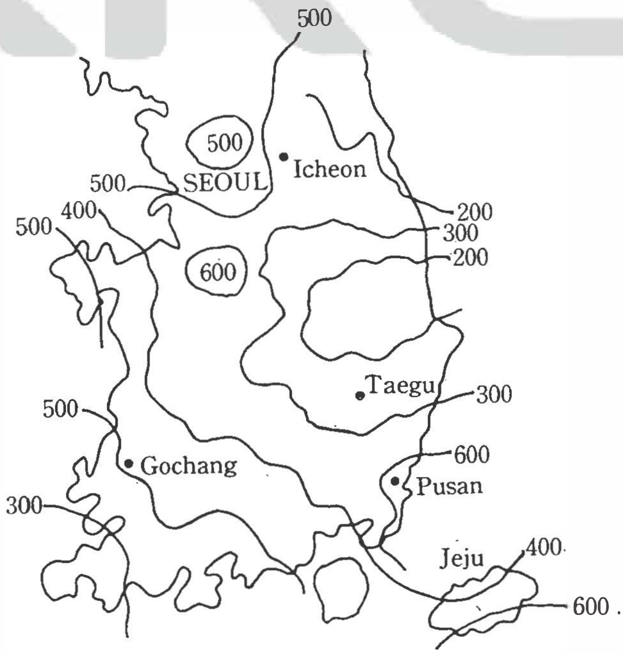
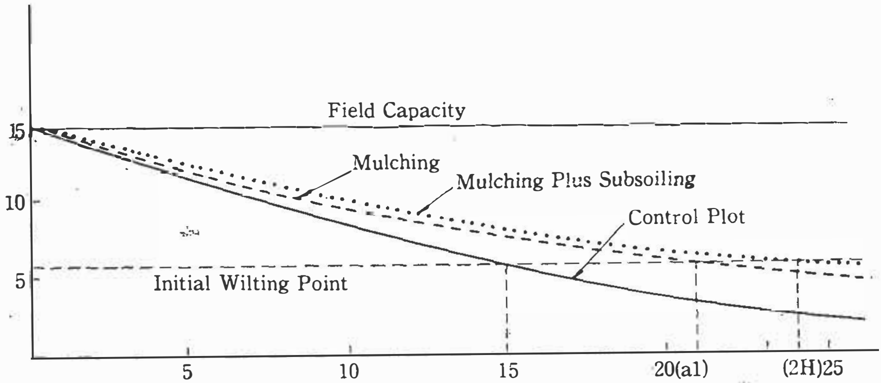


FIGURE A-2 SOIL MOISTURE CHANGES AS A FUNCTION OF TIME AFTER RAINFALL FOR DIFFERENT MANAGEMENT TECHNIQUES



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