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한국의 경사지 밭의 토양 및 물의 보전 관리 전략

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Management Strategies to Conserve Soil and Water Qualities in the Sloping Uplands in Korea

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ABSTRACT

Soils in the sloping uplands in Korea are subject to intensive land use with high input of agrochemicals and are vulnerable to soil erosion. Development of the environmentally sound land management strategy is essential for a sustainable production system in the sloping upland. This report addresses the status of upland agriculture and the best management practices for the uplands toward the sustainable agriculture. More than 60% of Korean lands are forest and only 21% are cultivating paddy and upland. Uplands are about 7% of the total lands and about 62% of the uplands are in the slopes higher than 7%. Due to the site-specificity of the upland, many managerial and environmental problems are occurring, such as severe erosion, shallow surface soils with rocky fragments, and loadings of non-point source (NPS) contaminants into the watershed. Based on the field trials, most of the sloping uplands were classified as Suitability Class III-V and the major limiting factor was slope and rock fragments. Due to this, soils were over-applied with N fertilizer, even though N rate was the recommendation. This resulted in decreases in yield, degradation of soil quality and increases in N loading to the leachate. Various case studies drew management practices toward sustainable production systems. The suggested BMP on the managerial, vegetative, and structural options were to practice buffer strips along the edges of fields and streams, winter cover crop, contour and mulching farming, detention weir, diversion drains, grassed waterway, and slope arrangement. With these options, conservation effects such as reductions in raindrop impact, flow velocity, runoff and sediment loss, and rill and gully erosion were observed. The proper management practice is a key element of the conservation of the soil and water in the sloping upland.

Key words: Sloping uplands, Soil and water quality, Best management practice (BMP)

Ⅰ. Introduction

In modern agriculture, two distinct soil management objectives must be considered to assure the maintenance of profitable production levels while minimizing any potential negative effects on the environment. Until the mid-1980s, agriculture in Korea focused on increasing the crop productivity with using high levels of fertilizers and agrochemicals. However, this has caused a detrimental effect on soil and water qualities.

Most Korean land is occupied by forest and only 21% is cultivating paddy and upland soils, and areas of paddy soils are larger than those of upland soils (MAF, 2001). Areas of the upland soil (740,000 ha) are about 7% of the total land, and about 62% of the upland soils are located in the slopes higher than 7% (NIAST, 1992). Due to this topographical distribution, most of the upland soils are vulnerable to severe erosion. About 20tons/ha of upland soils are estimated to erode per year in Korea (Jung et al., 2001; Jung 2002; Yang and Jung, 2000, 2001; Yoo and Jung, 1999).

Soil erosion from the sloping upland can deteriorate the soil productivity and water quality of the agricultural watershed. The continuous and intensive cultivation of crops in these sloping uplands can cause severe soil erosion, degrade soil quality and require more agrochemicals to maintain crop productivity. A specific management strategy to conserve soil and water environment and maintain the sustainable productivity in the sloping upland is strongly required.

As of 1997, Korean government promulgated the Environmentally-sound Agriculture Promotion Law in order to implement sustainable production while minimizing the environmental deterioration. The major objective of this law is to produce safe food and conserve the environment

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by the proper use of chemical fertilizers and pesticides, the adoption of integrated nutrient management (INM) and pest management (IPM), and recycling agricultural organic resources, etc. This goal can be achieved by the best management practices (BMP), which are site-specific. Many research efforts are being made recently by public and private sectors to develop the BMP for sustainable agriculture, especially in the sloping upland.

In this paper, we will discuss in brief about the status of upland agriculture and the case study results on the development of management practices toward the sustainable production as well as the conservation of soil and water qualities in the degrading sloping upland in Korea

II. Status of Sloping Upland Agriculture in Korea

1. Cultivation Areas and Productions of Crops

Table 1 compares the changes of planted areas and productions of major upland crops in the last decade. Areas and production of vegetables and orchards showed the increasing trend but those of other upland crops were decreasing. The corresponding parameters for rice were slightly decreased.

2. Topography

Most of the upland soils are located in the sloping fans, valleys, mountain foot and hilly areas as shown in Table 2 and 3 (NIAST, 1992). About 62% of the upland soils are located at slopes greater than 7%. Table 4 shows that higher than 20% of upland uses are subject to soil erosions in the ranges from Class II (eroded) to Class III (severely eroded). A similar trend is revealed for the orchard and grassland uses. Thus, land use to produce the conventional food crops, vegetables, and potato etc. in this topography requires labor-intensive management with higher input of agrochemicals and less dependence of agricultural machinery.

Table 1. Cultivating areas and productions of major upland crops (MAF, 2001).

Parameters	Year	Food Crops						Vegetables	Oil and Cash	Orchards
		Rice	Barley	Pulse	Potato	Misc. Grains	Subtotal			
Planted Areas (ha)	1992	1,157	103	135	33	50	1,478	356	129	147
	1997	1,052	70	122	30	41	1,315	364	108	176
	2000	1,072	68	107	25	46	1,318	386	92	173
Production (×1000 ton, as grain)	1992	5,331	315	212	105	243	6,206	8,276	88	2,090
	1997	5,476	292	189	86	213	5,476	9,685	79	2,300
	2000	5,291	163	134	75	248	5,911	10,483	64	2,429

Table 2. Topographical distribution of the Korean soils (unit: ha) (National Institute of Agricultural Science and Technology: NIAST, 1992).

Land Use	Sand dune	Plain	Alluvial fan	Valley	Diluvium terrace	Mountain foot	Rolling to hilly	Mountain	Volcanic ash	Total
Upland	1,075	73,954	65,922	284,800	18,658	214,869	145,326	34,268	39,587	878,501
Paddy	1,979	507,493	39,608	590,889	51,028	88,902	2,148	57	6,145	1,288,249
Orchard	2	16,337	8,168	28,174	2,323	21,503	27,839	5,812	8,663	119,011
Grassland	262	2,892	425	1,658	176	7,977	12,588	12,532	63,999	102,846
Forest	738	10,679	8,255	48,169	18,855	260,828	1,504,558	4,528,345	24,758	6,425,227

Table 3. Distribution areas of the Korea soils based on the slopes (unit: ha) (NIAST, 1992).

Land Use	0-2%	2-7%	7-15%	15-30%	30-60%	60-100%	Total
Upland	77,896	259,730	339,586	175,508	23,181	2,600	878,501
Paddy	550,332	477,677	215,480	44,726	34	1	1,288,249
Orchard	17,891	28,534	42,246	25,815	3,809	716	119,011
Grassland	3,326	23,495	39,579	20,736	14,146	1,564	102,846
Forest	10,854	44,033	205,501	571,062	2,106,288	3,487,489	6,425,227

Table 4. Distribution areas of the Korean soils based on the degree of surface soil erosion (unit: ha) (NIAST, 1992).

Land Uses	Erosion Classes				Total
	None to slightly eroded (I)	Eroded (II)	Severely eroded (III)	Gullied (IV)	
Upland	700,327	171,228	6,798	148	878,501
Orchard	84,113	33,231	1,618	42	119,011
Grassland	84,672	17,313	746	115	102,846
Forest	853,639	5,305,349	227,484	38,755	6,425,227

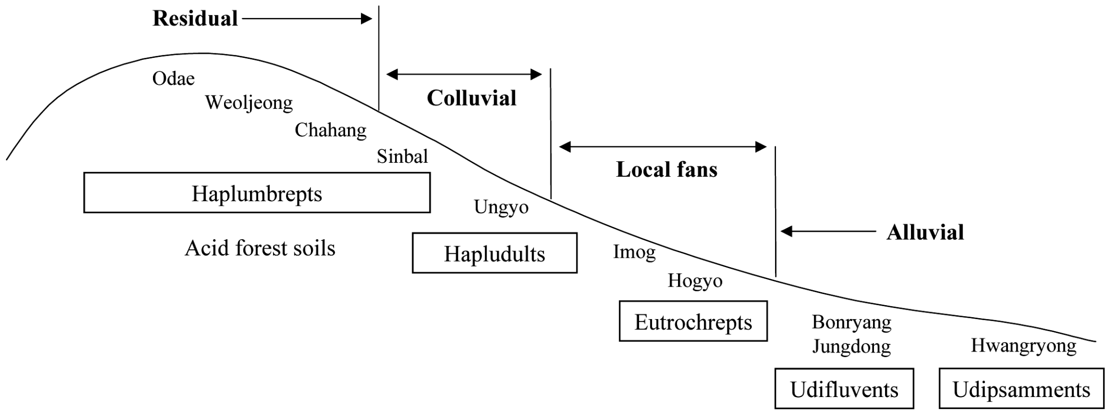

Fig. 1. Typical soil catena of the sloping alpine upland in Pyeongchang County, Kangwon Province.

This results in higher costs in agricultural production as well as higher risks of water pollution in the watershed due to erosion. Thus, a site-specific management practice for the sustainable production system is required in the sloping upland areas.

3. Soil Taxonomy

Based on soil taxonomy, 390 soil series are recognizable in Korea. Because of a warm temperature climate with moderately high rainfall in summer with an average of 1275 mm, most of the Korean soils in the coastal plain, alluvium plain, terraces, hilly land and low mountains are relatively deep and well oxidized. Two-thirds of parent materials of Korean soils are mostly granites and granite gneisses. Due to these parent materials the Korean soils are generally acidic in nature and coarse-textured. This nature under the thermic temperature regime with high precipitation resulted in highly weathered and leached soils of acidic, low organic matter content and low cation exchange capacity (CEC).

Soils of Korea range from very young to old or mature. In general, soils in the terraces, rolling peneplaine, and hilly lands are of old materials, and soils of the tide-water region in the coastal plains and river wash of levee in the flood plains are of young materials. According to the soil taxonomy system, soils in South Korea have been classified into 7 soil orders, 19 suborders, 29 great groups, 390 soil series, 501 soil types, and 1,288 soil phases (NIAST, 1992, 2000). The dominant soils in Korea are Inceptisols and Entisols. The Alfisols, Ultisols, Histosols, Mollisols and Andisols are recognized, but are less predominant. Inceptisols, Entisols, Alfisols, and Ultisols are the major soil orders used for upland and paddy soils. Andisols developed on volcanic ash materials are mostly in Jeju and Ulreung Islnads.

4. Soil Catena

The complicated geographic nature, climate and vegetation have brought about wide ranges of soils. Hilly topography and heavy monsoon rain cause a considerable movement of fine particles from the land directly into the water body. As a result, soils on sloping areas are shallow and very coarse. The textures of the soils in the river basins are also coarse due to flooding.

Fig. 1 is the typical patterns of the soil catena developed on the high mountainous sloping land in Pyeongchang County. In the high mountains the soils are acid forest soils of Haplumbrepts. The Odae soil series is a member of the coarse loamy mesic family of the Humic Lithic Dystrudepts. These soils are shallow with very dark brown A horizons, and thin yellowish brown gravelly and stony sandy loam B horizons overlying hard bedrocks within 50 cm of the surface (NIAST, 2000). On the soil surface thin to moderately thin Oe layer has accumulated. Weoljeong, Chahang and Sinbul series are the Humic Dystrudepts of which organic matter contents in A horizon are 4 to 8 percent.

5. Chemical Characteristics of Upland Soils

Table 5 shows the chemical properties of the upland soils, the suggested optimum ranges of the respective parameters for crop cultivation, and the comparative ratios between the two parameters. The ratios are classified into 'insufficient' when the analyzed soil properties are lower than the optimum ranges recommended by Rural Development Agency (RDA), 'optimum' when soil properties fit into the optimum ranges, and 'excess' when data exceed the recommendation.

As shown in Table 5, upland soils are acidic and low in organic matter. Chemical parameters such as pH, OM, Exc. Ca and Mg are generally in the 'insufficient' but to a less extent in the 'optimum' ranges. Contents of the available phosphate are, however, increasing constantly with time and exceeding the optimum ranges. This might be contributed to the retention of phosphate in the soils due to the continuous and over application of fertilizers.

Over the years, the chemical parameters of the plastic film house soils show a more drastic change than those of the upland soil and chemical parameters except pH are to a larger extent in the 'excess' ranges. Accumulation of salts especially phosphate is of primary concern. Frequently reported are physical and chemical problems inherent from salt accumulations and management, such as drainage, water use, higher bulk density due to machinery operation, and high salinity, etc.

6. Criteria for Upland Use Recommendation in Korea

Decisions on land use and the corresponding crop's adaptability rely on soil characteristics and many other factors such as climate, socio-economic merit, capital, and farmer's capability. However, recommendations for land use cannot consider all of these important parameters. Thus, in Korea, physical and chemical characteristics, along with soil factors limiting and/or interfering crop growth in that land, are primarily considered as a criteria for land use recommendation (NIAST, 1992). Whether the lands use is upland or others, the suitability is evaluated based on the soil characteristics, and the upper and lower

Table 5. The selected chemical properties of the upland and plastic film house soils (Park, 2001).

Land Uses	Year		pH	OM	Ava. P2O5	Exc. K	Exc. Ca	Exc. Mg
			(1:5)	g/kg	mg/kg	-------- cmolc/kg --------		
Upland Soils	'64 - '68		5.7	20	114	0.32	4.2	1.2
	'76 - '80		5.9	20	195	0.47	5.0	1.9
	'85 - '88		5.8	19	231	0.59	4.6	1.4
	'97		5.6	24	577	0.80	4.5	1.4
	Optimum ranges		6.0-6.5	20-30	300-500	0.5-0.6	5.0-6.0	1.5-2.0
	Ratio (%)¶	Insufficient	76.9	33.0	21.0	30.9	63.9	64.5
		Optimum	13.4	46.7	27.4	10.7	15.8	18.3
		Excess	9.7	20.3	51.6	58.4	20.3	17.2
Plastic Film House Soils	'76 - '80		5.8	22	811	1.08	6.0	2.5
	'80 - '89		5.8	26	945	1.01	6.4	2.3
	'91 - '93		6.0	31	861	1.07	5.9	1.9
	'98		6.0	35	1,092	1.27	6.0	2.5
	Optimum ranges		6.0-6.5	20-30	350-500	0.7-0.8	5.0-6.0	1.5-2.5
	Ratio (%)¶	Insufficient	46.4	20.7	12.7	23.4	29.8	27.9
		Optimum	29.8	24.5	7.4	6.0	17.8	18.9
		Excess	26.8	54.8	79.9	70.6	52.4	53.2

¶ Ratios were calculated based on the '97 and '98 data for upland soils and plastic film house soils, respectively, as compared to the optimum ranges for crop growth in the respective land use. Data shown in the Table are average data over at least several hundreds samples.

Table 6. Selected parameters and classification criteria adopted in the soil survey for characterizing soil properties and land management in Korea (NIAST, 1992).

Parameters	Classification Criteria or Descriptions
Slope (%)	A(level to nearly level: 0～2); B(gently sloping: 2～7); C(sloping: 7～15); D(moderately steep: 15～30); E(steep: 30～60); F(very steep: 60～100)
Drainage	Very poorly drained; Poorly drained; Somewhat poorly drained; Imperfectly drained; Moderately well drained; Well drained; Somewhat excessively drained; Excessively drained
Soil Reaction (pH)	Extremely acid (<4.5); Very strongly acid (4.5～5.0); Strongly acid (5.1～5.5); Medium acid (5.6～6.0); Slightly acid (6.1～6.5); Neutral (6.6～7.3); Mildly alkaline (7.4～7.8); Moderately alkaline (7.9～8.4); Strongly alkaline (8.5～9.0); Very strongly alkaline (>9.0)
Erosion Class	Slightly eroded (Class I); Eroded (Class II); Severely eroded (Class III); Gully (Class IV)
Permeability (cm/hr)	Very slow (<0.1); Slow(0.1～0.5); Moderately slow(0.5～2.0); Moderate(2.0～6.0); Moderately rapid(6.0～12.0); Rapid(12.0～25.0); Very rapid(>25.0)
Runoff	Ponded; very slow; slow; medium; rapid; very rapid
Soil Depth (cm)	Very shallow (0～20); Shallow (20～50); Moderately deep or shallow(50～100); Deep(100～150); Very deep(>150)
Organic Matter (%)	Low (<1.0); Moderately low(1.0～2.0); Medium(2.0～3.0); Moderately high(3.0～5.0); High(>5.0)
CEC (cmolc/kg)	Low (<5); Moderately low(5～10); Medium(10～15); Moderately high(15～20); High(>20)
Management Problem	Salts; Flood hazard; High water table; Drought; Permeability; Soil structure; Slope
Fertility Status	Low; Moderately low; Moderate; Moderately high; high
Land Use	P(irrigated rice); C(cultivated upland crops); O(orchard and mulberry); G(grassland); F(forest); U(urban); X(not suitable for agriculture)

Table 7. Criteria for the upland use recommendation (NIAST, 1992).

Characteristics	Criteria for Upland Use Recommendation
Topography	Flat land, terrace, local valley, hill, and mountain foot slope with slopes less than 15%
Soil Drainage	"Moderately well drained" to "well drained" ranges. However, lands in planes can include "somewhat excessively drained or excessively drained" soils
Soil Texture	"clay loam", ''sand loam", "silty sand loam", "silt loam" ranges. But "well drained" clayey soil and "moderately well drained" sandy soils can be included
Soil Depth	>50cm when rocky fragments or hardpans exit; However, in case stone or sandy layers exist, depth should be higher than 25cm.
Rock Fragments in Surface Soil	No or less of rocky fragments on surface soil or in soil profile.
Erosion Status	Slightly eroded (Class I) or Eroded (Class II); However, lands should not expose to severe erosion

Table 8. Difference between the current land use and the recommended land use (NIAST, 1992).

Land Uses	Current Land Use Status		Recommended Land Uses		Differences	
	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)
Upland	878,501	9.2	1,017,358	10.6	138,857	1.4
Paddy	1,288,249	13.4	1,257,352	13.1	Δ30,897	Δ0.3
Orchard	119,011	1.2	444,700	4.6	325,689	3.4
Grassland	102,849	1.1	2,226,826	18.1	2,123,980	22.2
Forest	6,425,227	67.1	3,867,598	14.5	Δ2,557,629	Δ26.7
Others	763,533	8.0	763,533	11.4	-	-
Total	9,577,367	100.0	9,577,367	100.0	-	-

limits for the soil properties in respective land use are provided. This is intended to help farmers or the land-owners decide the effective management practices based on the recommendation.

Table 6 shows the selected chemical and physical parameters, on which to base for characterizing and classifying the soil characteristics and subsequently for suggesting land management in the soil survey. Each parameter is classified into several levels, which can be used for characterizing the status and suitability of land use.

Using the above soil characteristics, criteria for land use recommendation is suggested separately for upland, paddy, orchard, grassland, and forest areas. Table 7 shows the criteria for upland use recommendation in Korea and Table 8 reveals the difference between the current land use and the recommended land use based on the soil survey data. Except for paddy and forest uses, the recommended upland uses could be expanded from 1.4 to 22.2% as compared to the current land use. In some sense, this indicates that the recommendation criteria for land use based on soil survey data are somewhat reasonable. About 27% of forests can be exploited as arable land or grassland.

7. Suitability Class of Upland Use Classification

The suitability class is the classification of land use based on the inherent soil characteristics, topography and many other environmental factors limiting land uses, in which data are provided from the scientific soil survey. Characterizing the degree and extent of limitation to crop production by environmental factors can on the other hand suggest the management strategy of land and crop selection criteria.

In Korea, the suitability class of land uses is divided into five classes (I to V) for each of the land classification categories (upland, paddy, orchard and mulberry, grassland and forest), based on the adaptability of soil conditions, superiority or inferiority of crop productivity, and degree of difficulty in land management. Classes I to IV can be applied to the respective land category, but class V is the inappropriate soil for land use at each category.

Crop productivity is highest in Class I land and lowest in Class IV (Table 9). However, the practical productivity is not proportional to the suitability classes. In a certain case, productivity in Class II is higher than that in Class I. Simply, Class I is easier than Class II in soil management both practically and economically in order to achieve the yield goals. In suitability classes II-IV, since soil of each class contains limiting factors in land use and management, those limiting factors are listed in the suitability class. It is possible that certain soils have more than two limiting factors in each class, but the most influential factor is only listed. An explanation for

Table 9. The recommended criteria for the suitability class for upland use in Korea based on the soil conditions.

	Parameters	Classes for the degree of suitability as upland use			
		I	II	III	IV
Definition and Requirements	Productivity	High	Medium	Low	Very low
	Management options for cultivation	Easy for IC and no limit for CS and SM[¶]	Possible for IC but slight limit for CS and SM	Special techniques are needed for soil and crop management due to severe limitation as upland use	Same as class III but an economic net return might be impossible
Selected Soil Conditions as Limiting factor	Drainage	Well and moderately well drained	Same as Class I plus imperfectly drained	Same as Class II plus excessively drained	Same as Class III plus poorly drained
	Texture[§]	CL; SiL; SL; SiSL	C; CL; SiCL; SL; SiSL	C; CL; SiL; SL; SiSL; S	C; CL; SiL; SL; SiSL; S
	Effective soil depth (cm)	>100	50～100	20～50	20～50
	Slopes (%)	<2	2～7	7～15	15～30
	Erosion class	None to slightly eroded (Class I)	Eroded (Class II)	Eroded～severely eroded (Class III)	Severely eroded
	Layer of sand or stoniness	>50	25～50	10～25	10～25
	Rock fragments	None	None	Gravel	Stone

¶ IC, CS and SM : Intensive Cropping, Crop Selection and Soil Management, respectively.

§ CL, SiL, SL, SiSL, C and S: clay loam, silt loam, sand loam, silty sand loam, clay and sand, respectively.

Table 10. Distribution areas of the Korean soils based on the land use suitability (unit: ha) (NIAST, 1992).

Land Uses	Areas of Suitability Classes for Land Uses					Total
	Class I	Class II	Class III	Class IV	Class V	
Upland	45,073	238,983	321,887	206,080	66,461	878,501
Paddy	183,037	368,391	487,938	217,201	31,682	1,288,249
Orchard	23,869	39,561	28,482	21,449	5,460	119,011
Forest	123,759	576,149	1,614,680	2,539,942	1,540,655	6,425,227

each suitability class is summarized as follows:

- Class I: High soil productivity; Possible for the intensive cultivation; No limitation in soil management
- Class II: Moderate soil productivity; Possible for intensive cultivation but some limitation is expected in soil management
- Class III: Low soil productivity; Severe limitations in soil management and crop cultivation
- Class IV: Very low soil productivity; Very severe limitations in soil management and crop cultivation, thus this class is not economically viable for crop production
- Class V: Below the Classes I-IV.

Limiting factors commonly used in defining the suitability class II-IV are as follows: slope, waterlogged condition, stoniness, sandiness, heavy clayey soil, salt, acid sulfate soil due to presence of sulfate salts within 100 cm of soil profile, immature soil, hardpan, rocky fragments, and erosion etc. Table 9 summarizes the recommended criteria for the suitability class for upland use in Korea based on the soil conditions (NIAST, 1992).

Table 10 shows the distribution areas of each suitability class for land use classification category. The majority of the uplands and others are in Classes II-IV, indicating there exist many limiting factors in soils for crop productivity.

8. Best Management Practices (BMP) in the Sloping Alpine Uplands

Adoption of the sustainable production systems and natural resource conservation in the sloping upland is critically needed in Korea to meet the goals for productivity and environmental conservation. Even though farmers follow the guidelines on land classification, management and crop selection, yield prediction in the field is erratic in many cases. Thus, the site-specific management strategies should be developed in situ. The Best Management Practice (BMP) is the best tool for accomplishing the goals of the sustainable agriculture especially in the sloping uplands. BMP is a practice or combination of practices that is determined by a state (or designated area-wide planning agency), after problem assessment, examination of alternative practices and appropriate public participation, and is the most effective practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals (Bailey and Waddell, 1979). Thus BMP should be agronomically and environmentally effective, economically feasible, socially acceptable and technically implementable in any type of field. Also BMP is site-specific.

We have conducted a series of researches on the best management practices (BMP) in the sloping uplands in line with sustainable agriculture. Some of the results from case studies are introduced in here.

A. Issues in the sloping Alpine Agriculture in Kangwon Province

Lands located at the elevation higher than 600m and 400-600m are defined as ‘alpine’ (highland or mountainous) and ‘semi-alpine’, respectively, in Korea. Climates in the alpine lands are cool in summer, cold in winter and high in precipitation. Due to the advantage of cool temperature during summer, potato and vegetables such as Chinese cabbage and radish are mostly cultivated as the cash crops in the alpine regions. Farmers make a high level of profits from alpine agriculture, thus areas and production of vegetables are constantly increasing. In the alpine regions, many lands are reclaimed from the forest. About 20 % of the total arable lands are located at elevation higher than 200m (NIAST, 1992). In Kangwon Province, Northeastern part of South Korea, the alpine land area is 16,301 ha and this is equivalent to 98% of the total alpine lands in Korea (Jung et al., 2001, 2002). Higher than 70% of the alpine lands have slopes greater than 7%

Table 11. Distribution of soil series at each category of land classification in Pyeongchang County (NIAST, 1999, 2000; Jung et al., 2001, 2002).

Land Use	Suitability Classes					
	Class I	Limiting Factors	Class II	Class III	Class IV	Class V
Upland	Anmi; Jungdong	Slopes	Anmi(B)[¶]; Imog (B)	Gagwha(C); Bancheon(C); Anmi(C,D); Ungyo(C); Imog(C); Chaahng(C); Pyeongan(C)	Gaghwa(D); Maji(C); Mui(C); Mitan(C); Bancheon(D); Songjeong(DE); Sinbul(C); Ungyo(D); Chahang(D); Pyeongan(D); Hogye(C)	Gaghwa(E,F); Gwanag(E,F); Mui(D,F); Mitan(D,E); Sinbul(D,E); Odae(D,E,F); Oesan(E,F); Ungyo(D,E); Weoljeong(E,F); Imog(C); Jangseong(E,F); Chahang(C,D,E); Cheongsim(E,F); Pyeongan(D,E); Pyeongchang(D,E); Hogye(C); Hwangryong; Rocky land; River land
		Rock Fragments		Maji; Hogye(B)	Maji(B)	
		Sand	Bonryang			
		Heavy Clay	Bancheon(B); Wangsan(B)			

¶ Letters from B to F in parenthesis indicate the degree of slopes, as specified in Table 6.

(NIAST, 1992). Due to the topography and site-specificity of the alpine lands, many managerial and environmental problems occur such as severe erosion, low productivity, intensive land use with high inputs of agrochemicals, shallow surface soils exposed with rocky fragments, difficulty in tillage, and loadings of non-point source (NPS) contaminants into the watershed, etc. Developments of management strategies toward the sustainable production systems in the alpine sloping land are, therefore, urgently needed.

Most of the lands in Pyeongchang-Gun, Kangwon Province, are located at an elevation higher than 600m, representing the typical alpine agricultural areas. There exist 25 soil series according to the soil taxonomy. The land use recommendation and the suitability class for the upland of Pyeongchang-Gun are summarized in Table 11, along with limiting factors for crop production.

Table 11 reveals that most of the sloping uplands are classified as Class III-V, indicating there are severe limitations in crop productivity when lands are used as upland. The major limiting factors are slope, rock fragments, sand, and heavy clay, of which slope and rock fragments are the most influential. Only two soil series out of twenty-five are classified as Suitability Class I. Most of the lands are located at slopes greater than 7%. This topography is subject to severe soil erosion which results in a high extents of rock fragment exposures on the surface soil, resulting in a lower holding capacity for water and nutrients. The typical soil catena in this County is shown in Fig. 1.

B. Fertilizer Management Problems in the Sloping Uplands

In the sloping alpine uplands, land is more susceptible to erosion resulting in a lot of rock fragment exposure on the surface soils. The sloping alpine uplands can be classified as Suitability Class III-IV based on the contents of rock fragments. Fertilizer recommendations in all countries are made on the basis of surface soil per unit area. The more rock fragments in soil, the less amount of soil, and the less fertilizer than the recommendation should be applied. However, farmers in the sloping alpine regions apply the mixed fertilizers more than the recommended (Jung et al., 2001; NIAST, 1999), based on their experience rather than soil testing. Soil testing considers even only soil particles passing through 2 mm sieve, but not rock fragments.

Jung (2002) conducted the pot experiments by making the artificial gravel contents of soils from 0 to 70%. Chinese cabbages were grown in the pot, and nitrogen fertilizers were applied with 60, 120, and 240 kg/ha rates. The N recommended rate for Chinese cabbage in the

Table 12. Effects of gravel content and N fertilizers on the qualities of soil and leachate (Jung, 2002).

	Gravel (%)	Nitrogen Fertilizer Rate (kg/ha)																	
		60	120	240	60	120	240	60	120	240	60	120	240	60	120	240	60	120	240
		pH ( )			EC (dS/m)			NH_4-N (mmol/kg)			NO_3-N (mmol/kg)			Leaf Length (cm)			N Leach (g/pot)		
Soil property	0	7.5	7.2	6.8	0.06	0.14	0.34	10.0	5.6	5.6	4.4	7.5	18.8	33	30	31			
	10	7.5	7.2	7.1	0.05	0.15	0.35	6.9	6.3	6.3	3.1	13.1	30.0	32	30	30			
	30	7.7	7.4	7.4	0.10	0.18	0.37	7.5	6.3	6.9	6.9	15.6	35.6	33	32	31			
	50	7.6	7.5	7.3	0.12	0.16	0.36	6.3	5.0	6.3	9.4	11.9	33.1	30	33	30			
	70	7.7	7.5	7.4	0.09	0.23	0.24	8.1	6.9	6.9	4.4	10.0	28.8	31	32	27			
Leachate property	0	7.5	7.7	7.6	13.5	17.1	25.0	15.4	18.2	74.2	32.2	32.2	37.8				0.05	0.07	0.17
	10	7.6	7.8	7.8	16.9	18.7	19.4	11.2	28.0	144	37.8	23.8	39.2				0.08	0.06	0.26
	30	7.8	7.6	7.6	12.7	20.5	20.2	15.4	88.2	139	21.0	35.0	42.0				0.08	0.23	0.44
	50	7.6	7.6	7.6	12.0	16.3	17.8	46.2	138	183	35.0	23.8	18.2				0.25	0.49	0.59
	70	7.7	7.7	7.4	12.1	11.2	16.0	92.4	277	338	29.4	51.8	28.0				0.41	1.08	1.53

sloping alpine upland is 240 kg/ha. At the bottom of the plot hose was connected to bottles to collect the leachate. Table 12 shows the soils characteristics after experiments, and chemical compositions of leachates analyzed right after the collection. pH, NH4-N and NO_3-N of the control experimental soil were 6.5, 28.0 and 16.8 mg/kg, respectively.

The pH of the soils was slightly decreased with increasing N fertilizer rates, irrespective of gravel contents. At each N rate, the pH of the soil was slightly increased also with increasing gravel contents. Electrical conductivities (EC) of soils were increased with both N rates and gravel contents. Changes of soil NO_3-N were greater than those of NH_4-N with N fertilizers and gravel contents. Contents of NO_3-N were sharply increased with increasing N rates, but those at each N rate were increased with increasing gravel contents. The leaf length (cm) of cabbage measured after 60 days were decreased with N rates at each of the gravel contents. The yield of cabbages as fresh weight was significantly decreased with increasing gravel contents (data not shown). At high levels of N and gravel, cabbages wilted due to the excessive N in the soils.

The pH of leachate did not change significantly with N rates and gravel contents. However, EC increased with N rates and was at least 1000 times higher than values reported in the freshwater. Gravel contents seemed to increase the EC of the leachates. Contents of NH_4-N in leachates were sharply increased with gravel contents and N rates, and those of NO_3-N showed a similar trend, but to a less extent. Amounts of N leached from the pot proportionally increased as increasing gravel contents and N rates. When the sloping alpine lands are eroded and have enough gravel contents on the surface, so called classified as the Suitability Class III-IV in land classification, soils are over-fertilized with N even at the recommendation rate. With this, soil qualities can be degraded and N loss to either groundwater or surface water can cause environmental problems such as eutrophication. The results clearly demonstrate that fertilizer management in the sloping land should be different from that in flat land and the characteristics of land classification need to be considered.

C. Best Management Practices in the Sloping Alpine Uplands

Our research group conducted various field researches to develop the BMP in the sloping alpine uplands and agricultural watersheds in the last several years in several places (Choi, et al., 1998, 2000; Jung et al., 1997, 1998, 2001, 2002; Yang and Jung, 2000, 2001). Field trials of the segment plots were installed in the sloping uplands

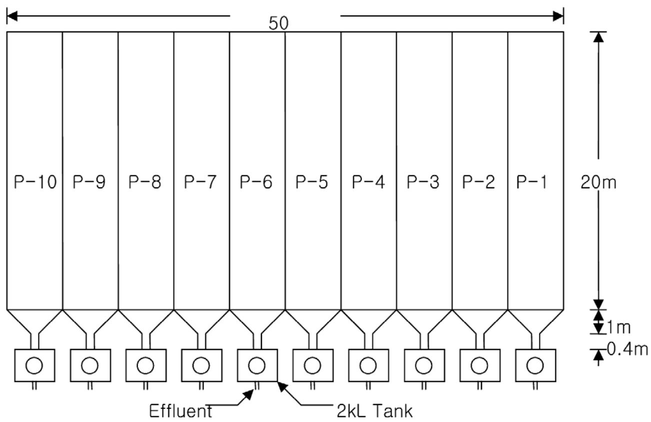

Fig. 2. Schematic of field plot experiment to develop the BMP in the sloping alpine uplands.

Table 13. Variations of soil chemical properties according to location of the corn plot.

Part[#]	pH	EC	OM	TN	NH_4-N	NO_3-N	P_2O_5	CEC
	( )	dS/m	g/kg	g/kg	―――――――	mg/kg	―――――――	cmolc/kg
Upper	4.93	0.07	25.8	2.0	6.62	54.96	226.1	9.84
Lower	4.80	0.12	38.3	2.7	10.61	86.21	386.6	11.67

[#] Sampling part in each segment plot.

Table 14. Effect of the managerial options on the soil loss and runoff in the sloping upland (Joo et al., 2002).

Managerial Options	Runoff (R, m^3)	Soil Loss (S, Kg)	S/R Ratio (kg/m^3)	Runoff Rate
No-till, Bare	9.11	21.67	2.38	50.9
Corn with Grass Buffer Strip	4.97	5.30	0.83	27.8
Corn Only	6.19	8.54	1.38	34.6
Up-Down Tillage	8.13	49.29	6.06	45.4
Potato with Grass Buffer strip	0.95	2.49	0.90	17.0
Potato Only	1.14	5.48	1.31	24.5

Table 15. Tillage, mulching and cropping combination reduced the runoff and soil loss in the segment plot (Jung et al., 2002).

Tillage	Mulching	Runoff (R, m^3)	Soil Loss (S, Kg)	S/R ratio (kg/m^3)	Runoff Rate (%)
Up-Down	Bare w/o crop	12.28	189.5	15.4	78.7
Slant	Bare w/o crop	11.61	129.2	11.1	70.2
	Potato only	6.62	55.2	8.3	24.7
	Potato with Straw Bundle at edge	6.65	13.4	2.0	42.1
	Potato with Mini Gravel Bag at edge	9.39	34.8	3.7	45.0
Contour	Control	5.49	36.0	6.6	40.5
	Straw Bundle	4.86	12.4	2.6	38.1

as shown in Fig. 2. Each plot was located at slopes greater than 7% and was separated from the neighboring one by dividends to prevent the water intervention between the plots. At the lower end, flumes, gutters, water level gauze, and water tanks were set to collect effluents and sediments.

Each plot received different combinations of treatments as follows:

- Land Use: Upland, paddy, bare soil, grassland, and forest
- Tillage methods: No-till, up-down, contour, and slant
- Crops: potato, corn, and grape
- Conservation managements: Grass way, mulching with minimum straw, vinyl, and mini gravel bags, bare fallow, and top-dressing
- Fertilizer: chemical and organic fertilizers
- Winter cover crop: No-cover and rye

Table 13 shows the spatial variability of the chemical characteristics of the soils collected from the upper and lower half segment of the plot. pH of the lower half of the plot was decreased as compared to that of the upper part. All of the chemical parameters of soils in the lower part were higher than those of soils in the upper part, mainly due to the soil erosion and runoff in the sloping upland (Joo et al., 2002). In this case, where the slope length is longer than 20m, an attempt to reduce the soil erosion and runoff such as terrace or grass buffer strip should be made to conserve soil and water qualities.

Table 14 indicates that grass buffer strip in the sloping upland could reduce the runoff (R), soil loss (S), S/R ratio and runoff rate (Joo et al., 2002). In this regard, potato revealed a better effect than corn, indicating the cropping system is very important factor for sustainable production system in the sloping upland (Ritter and Shirmohammadi, 2001).

Agricultural practices such as contour tillage, mulching, cropping system, and surface cover etc. are critical factors for the conservation of soil and water qualities in the sloping upland, mainly by reducing soil erosion (Lal and

Table 16. Effects of slope length on the soil quality in the sloping uplands.

Distance from slope base (m)	Surface soil depth (cm)	Gravel contents (%)	pH (1:1)	OM (g/kg)	CEC (cmolc/kg)	Av. P_2O_5 (mg/kg)	Infiltration rate (mm/hr)
20	35	36.4	4.7	49	15.1	150	6.8
50	25	33.4	4.3	43	13.3	293	5.2
100	15	32.4	4.2	32	13.1	291	4.8
150	5	31.3	4.4	27	12.4	98	4.4

Table 17. Conservation practices reduced the soil erosion, runoff, and nutrient loss to watershed.

Soil erosion reduction	From 85.7 ton/ha/yr to 13.9 ton/ha/yr
Runoff reduction	From 1,604 ton/ha/yr to 860 ton/ha/yr
Nutrient loss to watershed	From 72.8 kg/ha/yr to 26.8 kg/ha/yr
Effects of conservation practice on soil erosion	Terrace > water way > grassed waterway > grass buffer strip

Stewart, 1994; Yang and Jung, 2000, 2001). Jung et al., (2002) showed that contour tillage, surface cover, and cropping selection could control the runoff, runoff rate and soil loss significantly. Relatively simple materials such as rice straw bundle and mini-gravel bag of about 0.005m3 located at the edge of the plot were even very effective to control the soil erosion and runoff (Table 15). Also, slope management affected the soil quality revealing that soil chemical and physical properties were degraded as the slope length increased (Table 16) (Jung and Oh, 2002).

Jung and Oh (2002) applied the conservation practices in the sloping alpine upland field (3 ha) to monitor the soil loss, runoff and loads of eutrophic salts into the watershed for five years. The conservation practices that they employed were terrace, grassed waterway, waterfall buffer weir, contour tillage, mulching, and grass buffer strip, etc. Employing the conservation practices, as summarized in Table 17, significantly reduced soil loss, runoff and nutrient loss. Effects of practices were in the orders of terrace > water way > grassed waterway > grass buffer strip.

D. Agricultural Practices and Water Quality in the Agricultural Watershed

We have conducted also several field monitoring researches to assess the impacts of agricultural management on the water quality in the agricultural watershed. In the watershed, environmental factors such as household, population, livestock and land uses affecting the nutrient and losses were surveyed (Table 18). At the outlet of the watershed, automatic water level gauze was installed to determine the total quantity and velocity of the water. At

Table 18. The selected environmental parameters of the watershed in Chunchon, Korea.

Watershed Environment		Pollution Sources	Average Daily Load (kg/day)	
			Maximum	Minimum
Household	171	Runoff	2,712,542,000	985,000
Population	609			
Beef Cattle	945	T-N	20,400	10
Dairy Cows	46			
Swine	12	T-P	202.74	0.03
Poultry	244			
Dogs	192	SS	1.438.670	0.00
Paddy (km^2)	1.07			
Upland (km^2)	1.10	COD	21.320	0.00
Watershed (km^2)	14.74			

the several points of the streams near the arable fields, water samples were taken and analyzed for water quality parameters such as T-N, SS, T-P, COD etc. From these basic data, total amounts of eutrophic pollutant loads were estimated (Choi and Yang, 2002).

Tables 19 and 20 show the monthly loads of the eutrophic pollutants into the surface water from the agricultural fields (Choi and Yang, 2002). Water pollution parameters such as T-N, T-P, suspended solid (SS) and COD were proportionally increased with the amounts of rainfall. The average annual precipitation in Korea is 1,275 mm but most of them are concentrated during the monsoon season from June to September. Pollutant loads were highest during the monsoon season and those during the winter were very small. Agricultural uplands in this monitored area do not practice the conservation management options. Thus, a lot of nutrients and soil particles could transport

Table 19. Monthly pollutant loads into watershed as affected by the rainfall.

Months	Rainfall (mm)	Monthly Pollutant Loads			
		T-N (ton)	T-P (kg)	SS (ton)	COD (ton)
January	0.0 (0.0)#	1.06 (0.82)	7.41 (0.75)	0.5 (0.02)	0.4 (0.48)
February	0.0 (0.0)	0.50 (0.39)	3.94(0.40)	0.3 (0.01)	0.2 (0.24)
March	42.5 (2.8)	0.69 (0.54)	8.65(0.87)	0.2 (0.01)	0.4 (0.47)
April	73.7 (4.8)	8.71 (6.79)	44.06 (4.45)	5.8 (0.26)	3.2 (4.06)
May	98.0 (6.4)	5.02 (3.92)	24.32 (2.46)	4.1 (0.18)	1.2 (1.49)
June	92.7 (6.0)	5.32 (4.15)	32.38 (3.27)	3.5 (0.15)	1.7 (2.11)
July	215.4 (14.0)	14.3 (11.18)	94.15 (9.55)	18.9 (0.84)	7.7 (9.88)
August	559.6 (36.3)	61.9 (48.29)	545.4 (55.13)	1,840.4 (81)	43.9 (56.19)
September	346.6 (22.5)	22.5 (17.56)	170.4 (17.23)	401.2 (17.59)	17.3 (22.07)
October	92.3 (6.0)	5.17 (4.04)	36.28 (3.67)	3.7 (0.16)	1.4 (1.78)
November	15.7 (1.0)	2.48 (1.93)	18.23 (1.84)	1.7 (0.07)	0.9 (1.08)
December	5.2 (0.3)	0.51 (0.40)	3.69 (0.37)	0.3 (0.01)	0.1 (0.15)
Total	1,541.7(100)	128.19 (100)	989.15 (100)	2,280.7 (100)	78.2 (100)

Numbers in parenthesis indicate the percentage of the annual total.

Table 20. Daily loads of pollutants according to the daily rainfall amounts.

	Daily Rainfall (mm)			
	0~20	20~50	50~100	100 or greater
Number of data	610	37	7	5
T-N (kg/ha/day)	0.11	0.41	3.01	8.93
T-P (kg/ha/day)	0.69	3.41	23.86	102.28
SS (kg/ha/day)	0.37	2.05	30.33	411.16
COD (kg/ha/day)	0.04	0.25	1.73	10.78

to the surface water resulting in the possible eutrophication problem. Sustainable management practices should be adopted in this area.

Since soil erosion and runoff from the agricultural uplands cause the degradation of the surface and groundwater qualities in the watershed, the Government initiated the conservation program in the model villages by subsidizing farmers to practice the environmentally friendly farming. Most of the subsidies were related to the input materials and facilities, such as compost, soil conditioner, functional fertilizers, and tillage machinery etc. However, structural and vegetative options of the best management practices (BMP) and technical programs were omitted.

We compared the soil loss and Nitrogen loadings into the watershed between the conventional farming area and sustainable farming area where received the subsidy (Table 21, 22). Soil losses were similar in both areas and highest in the sloping uplands as compared to other land uses. Total N loadings were also similar in the two areas, and soil loss and fertilizers were the major contributor to the water pollution. These results indicate that the only managerial options are not effective tool to conserve soil and

Table 21. Soil loss from the conventional and sustainable farming areas.

Classification	Major Managerial Options	Land Use	Area (ha)	Soil Loss	
				MT/ha/yr	Total (MT/yr)
Conventional Practice Area	Fertilizers, Pesticide, up-down or slant till etc.	Forest	1,906	3.97	7,567 (42.2%)
		Paddy	652	1.72	1,121 (6.3%)
		Upland	652	14.15	9,226 (51.5%)
		Total	3,210	5.58(mean)	17,914 (100%)
Sustainable Practice Area	Compost, organic input, contour till etc.	Forest	1,176	0.33	388 (2.2%)
		Paddy	142	1.00	142 (0.8%)
		Upland	111	152.02	16,874 (97%)
		Total	1,429	12.18(mean)	17,404 (100%)

water qualities in the sloping uplands. The vegetative and structural options, along with managerial option of the BMP, should be combined and applied to the upland to reveal the uppermost effects on the soil and water conservation.

Table 22. N loading into watershed from the conventional and sustainable farming areas.

Pollution sources	Total N Loading into Watershed (kg N/year)	
	Conventional Practice Area	Sustainable Practice Area
Human	15,706	8,307
Livestock	65,732	15,984
Soil Loss	134,745	293,879
Fertilizers	159,974	31,038
Total	376,157	349,208

Table 23. Runoff water quality as affected by the conservation practices.

Managerial Options	pH (1:5)	EC (μS/cm)	NH_4-N	NO_3-N
Corn with Grass Buffer Strip	6.79	56.2	11.2	39.2
Corn Only	6.81	49.3	16.8	36.4
Up-Down Tillage	7.15	70.5	11.2	33.6
Potato with Grass Buffer strip	6.48	57.2	14.2	33.6
Potato Only	6.72	52.9	15.9	34.5

Table 24. Land use classification and management options in the sloping uplands for the sustainable production systems.

<table>
<tr><th rowspan="2"></th><th colspan="4">Slope (%)</th></tr>
<tr><th>2-7</th><th>7-15</th><th>15-30</th><th>30-60</th></tr>
<tr><td rowspan="3">Land Use</td><td colspan="2">General Upland Crop or Vegetables</td><td></td><td></td></tr>
<tr><td colspan="3">Orchard, Mulberry, or Intensive Sowing Grasslands</td><td></td></tr>
<tr><td></td><td colspan="3">Surface Sowing Grasslands or Fruit Cropping Trees</td></tr>
<tr><td rowspan="3">Land Conservation Management</td><td rowspan="2">Crop Cultivation with Contour and Diversion Ditch</td><td>Installment of Diversion Ditch (40×40 cm) at every 15-20 m</td><td>Installment of Diversion Ditch (50×50 cm) at every 10-15 m</td><td rowspan="2">Reclamation and Cultivation with Terrace Methods</td></tr>
<tr><td colspan="2">Installment of Back Slopes and Diversion Ditch; Grass Covering on Slopes</td></tr>
<tr><td colspan="4">Mulching with Grass or Others (e.g., vinyl) after Seeding and Transplanting: Fresh Grass (6000 kg/ha), Rice or Barley Straw (3000-4000 kg/ha)</td></tr>
</table>

Interval of diversion ditch (m) = {surface area of diversion ditch (cm^2)}×5/{Maximum annual average precipitation (mm)}

Table 25. The proposed best management practices (BMP) to reduce soil erosion and conserve water quality in the sloping alpine uplands.

Best Management Practices	Implementation	Conservation Effects
Buffer strips along edge of fields and streams	Cover with weeping love grass etc.	Reduce flow velocity, runoff and sediment loss
Contour farming	Contour strip cropping	Decrease runoff velocity and transport capacity; reduce rill erosion
Mulching farming	Mulching with vinyl, straw, mini-gravel bags, and weeds etc.	Decrease raindrop impact; decrease runoff and increase surface storage
Diversion drains	Diversion ditch at upland and forest border using rock and pipes	Reduce runoff velocity and capacity; reduce rill and gully erosion
Detention weir or pond	Small-scaled detention ponds in the waterway	Capture sediment, suspended solid, and adsorbed pollutants
Grassed waterway	Natural vegetation in the waterway	Decrease runoff velocity and gully erosion
Drainage	Subsurface drainage with rocks and pipes etc.	Decrease rill and gully erosion
Cover crop	Winter cover crops using rye and hairy vetch etc.	Minimize the periods of bare soil; decrease raindrop impact and rill erosion, improve soil structure
Slope arrangement	Slope arrangement at upland border with rocks or concrete	Decrease landslide and erosion

Sources: Jung et al. (2001, 2002); Yang and Jung (2000, 2001)

Table 23 shows that implementation of the conservation practices such as contour tillage, grass buffer strip and cropping system reduced the loads of N into the watershed, as demonstrated from the segment field plot experiment (Joo et al., 2002), as shown in Fig. 2. These case study results clearly demonstrated that the best management practices in the sloping upland are the most effective tool to conserve the soil and water qualities.

III. Management Strategies to Conserve Soil and Water Qualities in the Sloping Uplands: Summary

The amount of soil erosion, crop yields, soil properties, runoff and loadings of non-point source (NPS) pollutants such as N and P into the watershed were assessed, and integrating the various results drew the management practices in the sloping alpine upland toward the sustainable production systems. The major results on managerial, vegetative, and structural options obtained from these researches and others are integrated as in Tables 24 and 25.

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