Status and soil management problems of highland agriculture of the main mountainous region in the South Korea

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Abstract
A survey of the status and soil management problems of highland agriculture of the main mountainous region in S. Korea was attempted. The acreage of the highland agricultural farmland above elevation of 600 m producing high value vegetable was 9.3% of the total upland of the surveyed area. The major crops were Chinese cabbages, radishes and potatoes. Onions, carrots, water melons, red peppers, tobacco, apples, strawberries, and various crops were in minor. Since more than 20% of the farmlands were on the steep or very steep slope classes, the soils might be subject to severe water erosion, where immediate conservation practices should be necessary. The major problems in vegetable cropping of the surveyed area were poor soil management against soil erosion and heavy application of fertilizers. In this area, the phosphate, calcium and potassium contents were much higher than the national average of the surface soils of Korea. The farmer's application amount of nitrogen fertilizer ranged up to 1.4 times the recommended level by soil test, These rates of phosphate and potassium were 6.5 and 2.7 times, respectively. Heavy fertilizer application might cause soil accumulation of nutrients, and water pollution problems due to eroded soil materials. The total cost for recommended conservation practices on farm was 29.2 million US$, while that for reforestation for severely eroded farmland on steep slope was estimated as 1,218 million US$.

Key Words
Highland agriculture, soil erosion, fertilizer use, nutrient accumulation, reforestation cost.

Introduction
High value vegetable production in uplands above 600 m of elevation is classified as 'highland farming', and the uplands between 400 and 600 m elevation was classified as the sub-highland farm in South Korea. The major crops are high value vegetables including Chinese cabbages, radishes, potatoes, and other horticultural crops including flowers. The farming demands high input of nutrients. As these farmlands are located on high mountain slope, the soils are subject to severe erosion that causes non-point source problems of water body of the downstream (Jung *et al.* 1998; Park 2002). Especially, the Baegdu main mountainous area is the most important subject area for soil and water conservation project and the main source of the two main rivers, the Han River and the Nagdong River in Korea (Jung *et al.* 2006). Eroded soils cause serious water quality problems and sedimentation in water body of the down streams. Reforestation of such problem land should be dealt as national political approach (Gerhard 2004). A field survey was performed to identify soil management problems involved in this special crop production area, and costs of conservation management practices to protect soil erosion and water quality were estimated.

Methods
From the detailed soil survey map of Korea, the acreage of uplands is located in highlands of 32 Local Provinces in respect to elevation and slope classes. The present farm management practices and soil management problems were surveyed through farmer's interview, and soil samples were taken. The chemical and physical properties of the soil samples were analyzed using NAIST recommended methods (NAIST 2000a). The cost of reforestation of the upland subject to severe erosion, and to install on-farm conservation practices were estimated.

Results
Acreage distribution of vegetable farmland with respect to elevation and slope classes
The highland agricultural farmland above elevation of 600 m producing high value vegetable was 9.3% of the total upland of the surveyed area (Table 1). The major crops were Chinese cabbages, radishes and potatoes. The minor crops included Onions, carrots, water melons, red peppers, tobacco, apples, strawberries, flowers, and etc. The 85% of the highland farm above elevation of 600 m were in Gangwon Province.

Table 1. Area and elevation class distribution of vegetable farmlands in the survey area.

	Elevation (m)					
	<200	200 ~ 400	400 ~ 600	600 ~ 800	800<	Total
Area[A] (ha)	116,645 (40.5) [B]	100,401 (34.8)	44,375 (15.4)	21,898 (7.6)	4,957 (1.7)	288,276 (100)
Crops	Major crops: Chinese cabbages, radishes, potatoes Minor crops: Onions, carrots, water melons, red peppers, tobaccos , apples, strawberries, flowers and etc.					

[A]From the detailed soil survey map (NAIST 2008)
[B]Percentages were in parentheses

Table 2 shows areal distribution of the farmlands in the surveyed area. 84% of farmland was located on a slope over the 7 %. More than 20% were on the steep or very steep slope classes. This implies that these soils might be subject to severe water erosion, where immediate conservation practices would be necessary.

Table 2. Distribution of the farmlands in the surveyed area.

	Slope class						
	Plain (0 ~ 2%)	Weak slope (2 ~ 7%)	Mild slope (7 ~ 15%)	Moderate steep (15 ~ 30%)	Steep (30 ~ 60%)	Very steep (>60%)	Total
Area[A] (ha)	9,354 (3.2)	36,785 (12.8)	72,867 (25.3)	108,556 (37.6)	57,295 (19.9)	3,418 (1.2)	288,276 (100)

[A]From the detailed soil survey map (NAIST 2008)
Percentages were in parentheses

Soil management problems

The major problems in vegetable cropping in the highland agriculture of the surveyed area were poor soil management against soil erosion and heavy application of fertilizers. Figure 1 shows present status of crop cultivation in a highland farming, and soil erosion severity of a sloped land with bare soil. The soil erosion problem should be the first soil management problem in this area. The estimated soil erosion potential calculated by RUSLE ranged from 31 to 205 T ha/yr (data were not shown). The main problem of severe erosiveness was on steep and long slope, plowing up and down, and uncontrolled during bare fallow period.

Figure 1. Status of highland agriculture producing high value crops above 600 m elevation in Korea. Well controlled contour culture (left), and uncontrolled water erosion from bare soil (right).

In this area, the phosphate and calcium and potassium contents were much higher than the national average of surface soil of Korea (Table 3). Farmers used excessive fertilizers as shown in Table 4. The farmer's application amount of nitrogen fertilizer ranged up to 1.4 times to the recommended level by soil test. That of phosphate and potassium were 6.5 and 2.7 times, respectively, and, thus, excessive nutrient accumulation occurred The surface soil eroded from the farm with high organic matter and phosphate, and excessively used fertilizers should affect water quality of downstream. Immediate conservation action to protect water quality might be necessary.

Table 3. Soil chemical characteristics of the survey farm.

Soil properties		Highland agriculture		National average	
		Surveyed farms	Gangwon[A]	Upland[B]	Forest[B]
pH		5.7	6	5.5	5.5
OM(mg /kg)		28.5	21	23.1	50
Avia-P_2O_5 (mg /kg)		776	544	161	33.7
Exchangeable cations	Ca	6.1	4.8	4.8	4.6
(cmol /kg)	Mg	1.5	1.1	2	1.7
	K	1.2	0.7	0.3	0.4

[A]Gangwon Agricultural Science and Technology Institute
[B]A-horizons of the upland and forest soils from the Detailed Soil Survey Maps (NIAST 2008)

Table 4. Comparison of fertilizer use of farms and recommended amount based on soil test.

Crop	Fertilizer application (N-P_2O_5-K_2O kg/ha)		
	Recommended (A)	Farmers application (B)	B/A
Potatoes	137-33-114	245-203-203	1.8-6.1-1.8
Chinese Cabbages	238 -30–71	365-236-281	1.5-7.9-4.0
Radishes	252-30- 68	304-203-202	1.2-6.8-3.0
Carrots	180-40-74	263-208-247	1.5-5.2-3.3
Onions	233-30-155	276-199-254	1.2-6.6-1.6

A : Recommended amount of N, P_2O_5, and K_2O by soil test
B : Average amount of fertilizers by farmers in the Gangwon highland area

Cost necessary for reforestation of the severe erosive farmland.
Table 5 shows total cost necessary budget for conservation practice needs on farm application immediately of the total highland agricultural land of 71,643 ha above 400 m elevation. The cost required for the conservation practices was 29.15 million US$. Table 6 shows the cost of reforestation of farmlands where severe erosion might occur of which slope exceeded 30%. The total object acreage that required immediate conservation action was 6,375 ha. The total cost for reforestation for these acreage was 1,218 million US$ including land price and reforestation costs. This cost was 40 times to the conservation practices in Table 4. Additional initiatives for farmer were not included. Since the local government could not pay all these costs, the Government of Korea should take this cost into account as the national budget. Strong support might be necessary.

Table 5. Required on-farm conservation practices to reduce erosion from the severely erosive farmlands in the surveyed area.

Conservation practices[A]	Required (m)	Unit price (US$/m)	Estimated Budget (million US$)
Buffer strip	655,752	5.05	3.31
Vegetative drainage	139,686	20.51	2.86
Intercept back drainage	313,041	28.01	8.77
Boundary end ridge	227,080	7.87	1.79
Boundary end ridge with stone mesh beds	93,124	114.04	10.62
U side drain	27,192	17.17	0.47
Stone wall backslope	15,043	88.32	1.33
Total			29.15

Total object farmland : 71,643 ha
[A]Recommended conservation practices by Park (2002)

Table 6. Cost necessary for reforestation of the severe erosive farmland.

Slope Class	Object acreage	Cost (million US$) forestation		
	(ha)	Land price	Reforestation	Total cost
30~60%	4,398	567	274	841
60%<	1,977	193	123	590
Total	6,375	821	397	1,218
Remarks	Severely erosive Farm	12.9 US$/$m^2$ (GDI 2006)	6.2 US$/$m^2$	

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