Preliminary study on multifunctional role of upland fields.

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ABSTRACT

Various kinds of research have been carried out on the multifunctional role of agriculture, relating to paddy fields, which have received worldwide acceptance. For upland fields little or no research seems to have been done and therefore for countries in the Western countries such as Europe and U. S. A. where upland fields are dominant, there is lack of understanding for the role of the farmland.

In this study, preliminary study is carried out on the multifunctional role of upland. First, some main roles are reviewed after which some preliminary role and functions were examined. For example, waste products could be applied to farmland in agricultural production if their safety for human being and the environment can be ascertained. Some calculations have been carried out to determine the volume of waste products (sludge) that could be applied to upland. This is one of the important functions of evaluating uplands.

1. OBJECTIVE

At the recent World Water Forum (WWF) held in Japan in March 2003, multifunctional role of water and paddy agriculture was discussed and finally the concept was almost accepted by all countries of the world, including developing countries. Meanwhile, multifunctional role of upland fields has not been given the same treatment and there is lack of an in-depth study. In the USA and Europe where upland agriculture is dominant, their people do not seem to understand this concept. It is important, therefore, to look at the multifunctional role of water in upland fields to find out what roles can be assigned even though a casual look will point to huge negative functions for human beings and the environment. If these negative functions are confirmed through research, then the task will be set in finding ways to reduce their impact taking into consideration sustainable production. The identified positive roles would then have to be promoted within the concept of sustainable production synchronizing nature and environment.

Regarding the multifunctional role of paddies, some evaluation methods such as CVM (Contingent Valuation Method), Hedonic method, etc., have been used to classify such functions as flood preventión, water resources conservation, soil erosion prevention, waste management and others. In comparison with upland fields, only about 43% of values of the multifunctional role has been done (Mitsubishi Institute, 2001).

In this study, first, the multifunctional roles of upland have been sought from various points of views. Secondly, preliminary review has been carried out for landscape preservation of upland. And thirdly, some preliminary calculation was carried out to determine how much animal waste (sludge) could be applied to farmland. This is a case study but we can expect rough acceptable potential amounts; also it is important for their safety for human being and the environment to be confirmed prior to their application.

This must be a good start to the study and many more research is needed in order to evaluate those roles.

2. MULTIFUNCTIONAL ROLE

2.1 Area of upland

There are 1.4 billion ha of farmland in the whole world with 0.27 billion ha irrigated (just 19.9%). Out of the world total, 1.2 billion ha (89.3%) are uplands (FAOSTAT). In Asia, there are 180 million ha of farmland in total; 39.1% are irrigated and 73.2% are upland (Table 1). Upland is dominant on the worldwide scale, while in Asia there is a large area devoted to paddy fields. This is one reason for studies on multifunctional of water starting from paddy field in Asia. In USA and Europe, more than 99.0% of farmland is upland, leaving a small area devoted to paddy fields.

Table 1 Farmland (World)

Total area (1000ha)	Arable Land			Irrigated Area (ha)	Upland ratio(%)	Irrigation Area ratio(%)
	Rice, paddy field (2)	Upland field (1) - (2)	Total (1)			
World	146,029	1,218,209	**1,364,238**	**271,689**	89.3	19.9
Africa	7,755	171,968	**179,723**	**12,680**	95.7	7.1
Asia	130,475	355,779	**486,254**	**190,083**	73.2	39.1
Europe	583	289,212	**289,795**	**24,508**	99.8	8.5
North & Central America	1,940	257,276	**259,216**	**31,406**	99.3	12.1
Oceania	168	52,291	**52,459**	**2,674**	99.7	5.1
South America	5,109	91,682	**96,791**	**10,338**	94.7	10.7

(1000 ha)

Data Source; FAOSTAT(2000-2002)

2.2 History

It is important to grasp the history of upland (development). Basically, rice has been a staple food in Japan, therefore rice paddy has higher priority over other food crops. Upland fields development therefore has seen worse conditions in terms of water use and distance from the village, etc,. In addition, uplands have been developed on relatively permeable soils. Fortunately in Japan, volcanic ash soils are dominant and permeable making it possible for upland fields to be developed there. Recently, however, commercial crops have been produced especially near city suburbs. This has led to upland fields, including greenhouses, being developed in paddy field areas in lowlands.

2.3 Characteristics of Japanese surrounding condition

The average annual rainfall in Japan is relatively high (about 1,600 mm/yr), with a (relatively high) considerable amount of the rain falling in the summer. This is coupled with basically, a high humidity. More than half of upland fields in Japan are located on volcanic ash soils. These soils are highly permeable; have high water holding capacities, with a high phosphorus absorption capacity. Basically, this soil is not suitable for rice production and as mentioned earlier, upland fields developed worse conditions than that of rice paddy. But recently, commercial crop production has been done on rice paddy zones because rice production has been regulated by the government.

2.4 OECD study

OECD has abstracted basic multifunctional roles of farmland. They are summarized and listed below:

(i) Landscape preservation; Green tourism

(ii) Bio-diversification; Bio-preservation
(iii) Soil and Water Conservation;
(iv) Air conservation; Air pollution reduction
(v) Land Preservation; Flood prevention
(vi) Greenhouse gas reduction; CO_2 gas fixation
(vii) Rural activation; Green tourism, rural employment
(viii) Food security; Productive potential
(ix) Culture preservation; Ancient building, traditional preservation, etc.
(x) Institutional (Social) preservation; Farmers society
(xi) Miscellaneous; Waste management (Waste could be applied to farmland)

3. REVIEW (LANDSCAPE PRESERVATION)

Traditional research on multifunctional role, especially landscape preservation and environmental preservation, was reviewed from mainly Japanese case studies.

3.1 Landscape preservation

The National Institute for Agricultural Policy has calculated values for the multifunctional role of agriculture with the CVM method. According to this, about $25 billion value has been reported, including mountainous regions.

In Hokkaido (northern part of Japan, where upland agriculture is dominant), tourism resources were valued with the CVM method. Based on the Box-Cox method, Maruyama et al., (1995) reported values of $216 million for paddy field and $574 million for upland. Recreation function of tourism farmland is valued at $80 to $240 thousand and sunflower has a value of $760 thousand to preserve landscape using the CVM method (Demura and Kato, 1999). Demura and Yoshida (1999) valued the landscape generation function of rural village as $184 for dweller, and $86 for tourists.

3.2 Environmental Function

Amamiya et. al. reported that upland fields have lower functional value in terms of water purification compared with paddy, pasture and forests. However, in orchards there is a higher value for disaster prevention (as refuge), and a higher value for landscape preservation. Uplands have higher value in serving as refuge for hazardous materials such as heavy metals. Pastures score higher values in the landscape preservation and recreation function as they serve as CO_2 and atmospheric preservation, soil erosion prevention, disaster prevention, and water and air purification.

3.3 Other expected role

Japanese upland is different from those of US and European countries in terms of their history, agronomic practices, etc. For example, uplands are patched and are in harmony with paddies making this mixture unique. A mixture of paddy and upland is somehow interesting and creates such variation which could be evaluated for their various roles. In our country, upland has been developed basically from worse conditions far from the village. Recently, however, urban agriculture has been developed close to the cities producing commercial crops such as vegetables, fruits, etc. These could provide employment in restaurants and shops. In addition, upland can provide enough space for use as refuge from natural disaster such as earthquake, flood, etc., it is utilized properly.

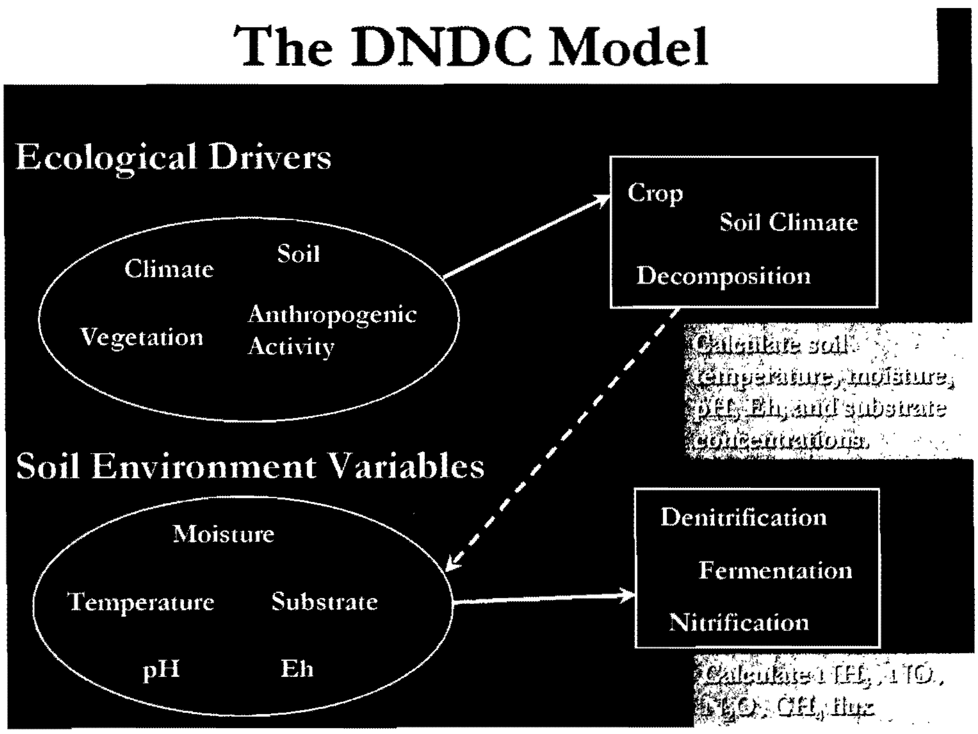
4. RECYCLING ROLE

Farmland could be a place to recycle organic wastes it their safety requirements for crops, human beings and the environment can be assured. How much volume and weight could be applied to farmland is a question that depends on soil, crop, and climate, etc. This should be decided scientifically taking into consideration a reduction in the impact on the environment. Because some organic materials such as compost products and sludge have nitrogen, phosphorus and potassium, etc, in their compositions, they could be useful for crops if they are managed properly. It is important, therefore, to quantify the optimal levels of application of waste products such as sludge.

4.1 Methodology

In this study, the DNDC (DeNitrification and DeComposition) model (Changsheng Li, 1995) was used to simulate carbon and nitrogen movement around the farmland due to application of organic wastes.

Schematic idea of the model is shown in Figure 1. The model which simulates carbon and nitrogen dynamics in the atmosphere, mainly greenhouse gases, requires various kinds of input parameters.



The target area is southern part of Kyushu (southern part of Japan) where an irrigation and drainage project has been planned. For simulation, some field data was collected but in case of missing data, default values in the model were used. The area involved is about 6,000 ha (upland area is 1,635 ha and rice paddy area is 475 ha), and project planned crops were selected for the simulation such as corn (maize), radish (vegetable) and rice (paddy). Example of the typical input data is shown in Table 2. The dominant soil in the target area is Ando-sol (typical Japanese volcanic ash soil), which is light, permeable; have high water holding capacity, etc. Daily meteorological data such as rainfall, temperature, radiation, sunshine hours, etc., were taken from the Japanese Meteorological Service's Database (AMEDAS, 2001). Nutrient types could be changed with changing C/N ratio.

Two standards of compost application rates existing in Japan were adapted for use in the simulation process. The first is 80 kg/ha recommended by the Kagoshima Prefecture Agricultural Experiment Station in 1998; and the second is 200 kg/ha, the general recommendation used all over Japan (Miwa and Ogawa, 1988). The simulation was carried out for three years.

4.2 Result and Discussion

Table 3 to 5 shows some examples of simulation results including leached nitrate nitrogen, N_2O, CO_2 gas for different amounts (100 and 200 kg/ha) and types of nutrients (i.e., chemical, compost, compost/chemical mixture) for vegetable (radish) production.

Table.2 Input data (Example)

Land Use	Upland field (Corn, Radish) ,Rice Paddy
Soil Texture	Loam [Ando-sol]
Balk Density(g/cm^3)	0.78 [Ando-sol]
Soil pH	5.5 [Ando-sol]
Clay portion (%)	0.22 [Ando-sol]
Wilting Point (%)	0.22 [Ando-sol]
Field capacity (%)	0.56 [Ando-sol]
Total carbon (%)	0.06 [Ando-sol]
Porosity (%)	0.71 [Ando-sol]
Litter	0.08 *
Humas	0.12 *
Passive humus	0.8 *
Initial NO3−Concentration at soil Surface	3.0mg N/kg *
Initial NH4+ Concentration at soil surface	0.6mg N/kg *
Initial soil water content	0.49
Initial soil Temperature	4.4° C *
Carbon Ratio	0.0027 (4)

*:Model Default value

Table 3 Leached Nitrate Concentration (Vegetables)

	1st yr (ppm)	2nd yr (ppm)	3rd yr ppm)
Compost+Chemical Fertilizer (Total Nitrogen = 100kg/ha)	6.1	4.8	6.8
Chemical Fertilizer (Total Nitrogen = 100kg/ha)	8.6	7.9	9.2
Compost (Total Nitrogen = 100kg/ha)	6.0	5.5	7.0
Compost+Chemical Fertilizer (Total Nitrogen = 200kg/ha)	6.6	5.1	7.1
Chemical Fertilizer (Total Nitrogen = 200kg/ha)	11.2	10.6	12.7
Compost (Total Nitrogen = 200kg/ha)	6.8	5.2	7.3

Table 4 N_2O Gas Emission (Vegetables)

	1 st yr (kg/ha/yr)	2 nd yr (kg/ha/yr)	3 rd yr (kg/ha/yr)
Compost+Chemical Fertilizer (Total Nitrogen = 100kg/ha)	7.2	7.3	7.8
Chemical Fertilizer (Total Nitrogen = 100kg/ha)	9.5	8.9	9.0
Compost (Total Nitrogen = 100kg/ha)	4.1	4.2	4.5
Compost+Chemical Fertilizer (Total Nitrogen = 200kg/ha)	15.8	16.3	17.2
Chemical Fertilizer (Total Nitrogen = 200kg/ha)	17.3	16.7	17.0
Compost (Total Nitrogen = 200kg/ha)	6.2	6.5	6.6

Table 3 shows leached nitrogen concentration for three years. The nitrate nitrogen values changed year after year with the value of the second year being relatively smaller than the others. The values are larger for chemical nutrition compared with the others. The 200 kg/ha application rate of chemical nutrition induced more than 10 *ppm* of nitrogen concentration occasionally, which is more than domestic limiting standard value.

Table 4 shows N_2O emission amount, which is one of the most harmful greenhouse gases. Emission of N_2O is larger for chemical nutrition application than for those of the other methods applied which had values which were less than half the amount involving chemical nutrition. The emission value is almost the same throughout the simulation periods.

Table 5 shows CO_2 emission from the soil surface. The amount of CO_2 gas decreased year after year with that from chemical nutrition being smaller than those from compost or chemical/compost mixture. If the application rate is doubled (say, from 100 to 200 kg/ha), the emission amount does not decrease in the same order.

Table 5 Soil CO_2 Emissions (Vegetables)

	1 st yr (kg/ha/yr)	2 nd yr (kg/ha/yr)	3 rd yr (kg/ha/yr)
Compost+Chemical Fertilizer (Total Nitrogen = 100kg/ha)	19,869.4	16,331.5	14,349.7
Chemical Fertilizer (Total Nitrogen = 100kg/ha)	18,405.1	14,764.4	12,613.8
Compost (Total Nitrogen = 100kg/ha)	19,869.4	16,331.5	14,349.7
Compost+Chemical Fertilizer (Total Nitrogen = 200kg/ha)	21,447.5	18,746.4	17,289.4
Chemical Fertilizer (Total Nitrogen = 200kg/ha)	19,084.0	15,355.3	13,593.7
Compost (Total Nitrogen = 200kg/ha)	21,447.5	18,746.4	17,289.4

Table 6 shows the applicable organic nutrient matter rate in this region. This is based on actual field information (cropping coverage, paddy 457 ha, upland 1,635 ha). It is also based on some assumptions that total amount of manure is 3.33, 1.67, and 1.43 times of nitrogen.

Table 6 Applicable amount.

Type of Manure	Applicable amount (t /Area)		
	Paddy Field	Upland Field	Total
Cow	304.4	435.6	740.0
Pig	152.6	218.4	371.0
Chicken	130.7	187.0	317.7

Based on these assumptions, applicable rate of organic waste could be calculated. Finally, 740, 371, 317.7 tons of manure (sludge) could be applied with recommended standard (100 kg/ha/yr). In other words, upland fields can be able to accept 435.6, 218.4, and 187.0 tons of cow, pig, and chicken manure in a year respectively.

5. CONCLUSION

Multifunctional role of upland has been preliminarily dealt with. First of all, some important roles have been abstracted after which in terms of landscape preservation, studies of on the Japanese situation has been reviewed.

Next, applicable rate of organic waste to farmland was simulated based on some assumptions and the valuable results obtained are summarized as follows:

1. There are many multifunctional roles for uplands also.
2. Landscape preservation function is one of the important roles and some researchers have already given value to this.
3. Applicable rate of organic matter was calculated as 435.6, 218.4, and 187.0 tons of cow, pig, and chicken manure respectively. These could be applied to the upland if their safety

conditions regarding crops, human beings, and the environment could be ascertained.

It is quite important to extend these kinds of studies to enhance research output. In addition, further research is needed regarding mainly evaluation methodologies and evaluation examples.

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