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LAND USE FOR THE SUSTAINABLE AGRICULTURE : PROTECTION OF SLOPING LAND FROM HAZARDS, SALINIZATION, EROSION, USING THE AGRO-FORESTRY SYSTEM

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ABSTRACT

The 21st century's agriculture is now seeking for a sustainable agriculture free from water pollution, flood, erosion, and desertification.

This paper is focused on the sloping land use system in agro-forestry. This system is one of the sustainable land uses in which water harvest in dry land and array cultivation in humid land are included. Herein the Japanese traditional production system of paddy cultivation will be discussed as one of agro-forestries worth applying to the land use planning and the environmental conservation.

Land use systems for paddy field in lowland, upland field, and forest have been existed with the relation of interdependence in one water shed in Japan. A case study suggests a ratio between command areas of three land uses. A multi-lateral land use for sustainable agriculture in humid regions is proposed on the basis of water chain in watershed and topography.

INTRODUCTION AND OBJECTIVES

Agriculture depends on the land where farmers perform their agricultural production. The land is a production facility which is always under the influence of erosion and deposition because agricultural fields are mostly located on sloping land rather than alluvial flat land. Maintaining a field production potential is to prevent the land from devastation and infertility. The potential can be maintained not only by basic fertilizers, but also the physical properties of soil-water, a suitable soil structure created in the presence of organic materials. The water management of soil in response to growing stages is necessary to get the sustainable production

Table 1 Three types of hazards consisting of topographic and climatic conditions.

	flat field	sloping field
dry land	salinization	erosion, salinization
wet land	flood	erosion, inundation

in dry lands.

The land devastation is progressed mainly by erosion, flood and salinization. These dominant 3 factors have a close connection with topographic and climatic conditions. The flood hazard will be found in paddy fields on alluvial plains.

In this paper the land use for the prevention of erosion and salinization and effective water use for sloping land were investigated. A multi-lateral land use for the sustainable agriculture in humid land were proposed.

MATERIALS AND METHODS

A method used herein is mainly the surveying of land use. Land is a basic material in the agro-forestry system for the sustainable agriculture.

1. Salinization

Soil salinization occurs generally in arid and semi-arid regions while over irrigation in the dry season even in the tropical rain forest climate will make the soil sodic. Capillary water comes up with salts to the soil surface in dry condition. The water evaporates and salts remain on the surface. This salinization grows gradually until the land can not produce crops. The same case of salinization occurs where fields are often irrigated from under ground water. In some places where annual rain fall is less than 600 mm, the irrigation water with salinity is often supplied from deep wells, salinity in surface layer is concentrated for a long time to generate the sodic soil of infertility. Actually, when the soil is highly salinised, it will be of no use for agriculture. This is the beginning of desertification.

Too much rain fall and over irrigation in dry lands induce water table rising which causes to generate sodic soils. The world sodic soil is estimated at 1/3 of the dry lands in area. This soil is often observed in places where the amount of annual rainfall is less than the annual evapo-transpiration. We can see many sodic soils in the Sahara, the east coast of the Mediterranean, the Middle East, West China, the North-Eastern part of Thailand, Indonesia and others.

Reclamation for irrigated agriculture has been carried out in the Saheru around the Sahara desert from 1970 to 1980. The same area of reclamated land is reported in danger of sodic soil or impervious soil with

hard-pan which will easily make erosion in the rain, though some parts of them are still now classified as fertile soils. The reason for salinization is that they employed the high production method of modernized agriculture without regarding to natural conditions. If they continue in the same way of management, it is said that one-sixth of the good field in the Saheru will nake desert by the beginning of 21st Century.

The degree of salinization depends on the type of land-use and water management. The infertility including salinization can be avoided by the proper management of soil and water.

An average amount of rainfall in the terrain of the world is calculated to be between 670 and 840 mm. The area with this amount of rainfall is not always free from salinization. The area with less than 500 mm annual rainfall is always within the danger of emergent possibility of salinization. The area with annual rainfall of less than 400 mm will have the problems. The soil profile of arid zone consists basically of three layers. Carbonic salts deposit in surface layer, gypsum in sub-surface and sodium in sub-layer.

The conditions of emergency are categorized as follows, though it is difficult to analyze only by amount of the irrigation water because salinization can be avoidable by management.

(A) No-irrigated Land Use. R:annual rainfall, Ep:actual evapo-transpiration.

(a) If R > Ep, Salinization is generally not common. Even if it occurs, there are no big troubles.

(b) If R < Ep, there is the emergence possibility of salinization. Many places of fields and arable lands are in danger of salinization.

(B) Irrigated Land Use. I:amount of actual irrigation.

(a) R + I > Ep, Salinization is not common, provided the proper use of irrigation technique.

(b) R + I < Ep, The emergent conditions are existing. The sophisticated operation of water management will save salinization.

2. Erosion

The upland fields in the world is far larger than the paddy field in the area. Erosion in the upland occurs easily by rainfall, so that erosion hazard are very serious problems. Erosion problems can be found in many countries. For example, the Philippines and Indonesia also have erosion problems because their timber production and land development resulted from the deforestation.

Myanmar is located in the monsoon area, and three fourth of the area belongs to mountainous lands and hilly places where the slopping land is suffering from erosive soil movement. It is believed that more

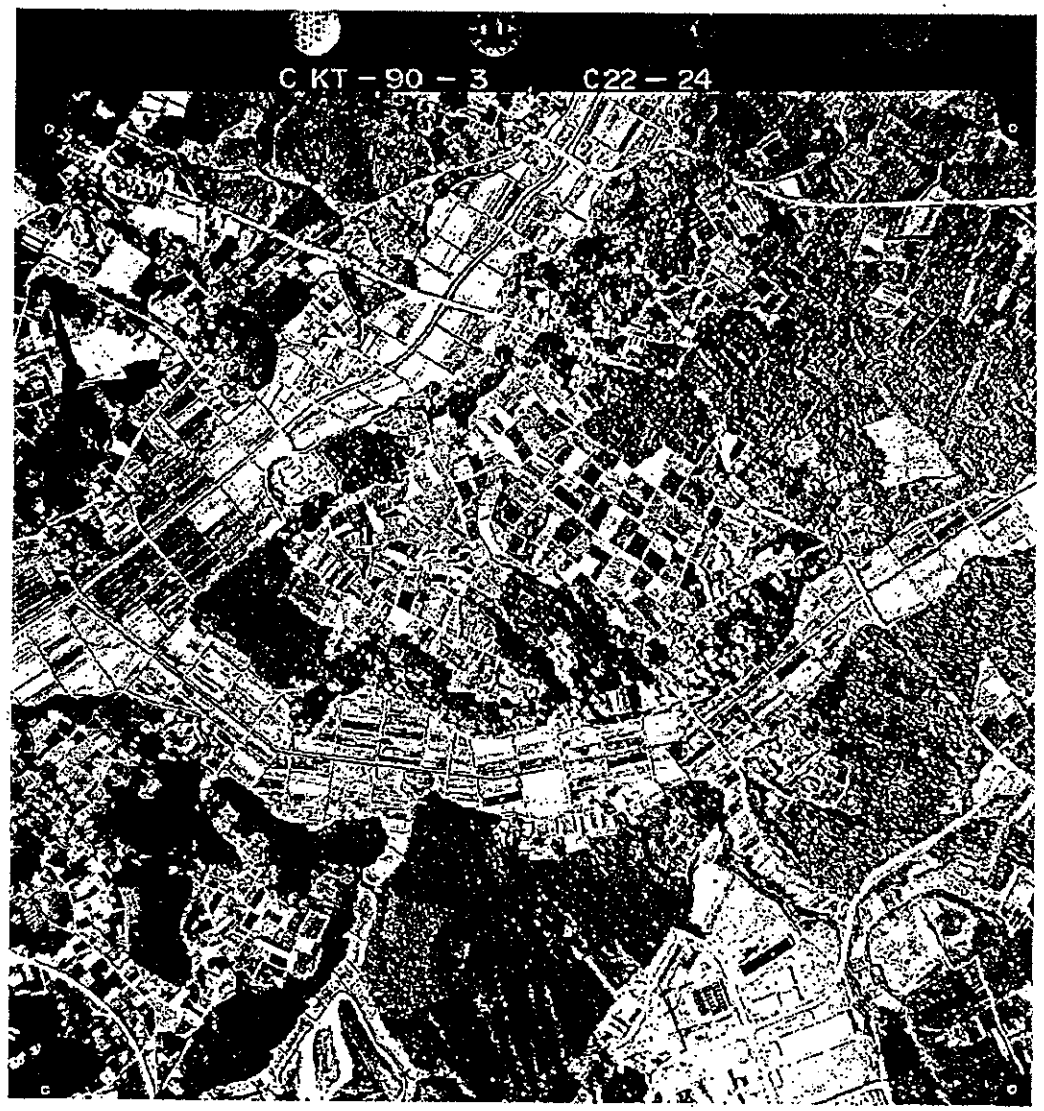

Figure 1 Photograph of land use, Ami-machi, Ibaraki-ken (1994)

than 30% of the soil is shared by strongly erosive soils. The rest of the land is flood land. The land with non erosion is mostly occupied by flood plain.

In Pakistan there are erosion hazards in the western region where sodic soils and desert are located. Dams and ponds are being filled with clay by erosion. Particularly sodic soil makes an impermeable surface.

Wind erosion is found not only in dry land but also in humid region like Japan where strong wind makes sand dunes with no vegetation. In dry land an irrigation system for wind erosion protection can be employed. Wind-bread forests are effective to loosen the wind erosion hazard.

Investigation of land use for agro-forestry

1. Dry land

Dry land belongs here to semi-arid to arid regions where annual rain fall is less than 500 mm. Sodic soils belong to the soils in process of desertification.

Many studies on the run-off agriculture and the agro-forestry in dry lands have been done particularly in the countries suffering from water shortage, because agro-forestry is seen as one of the sustainable land use for agriculture.

Agricultural soil in dry land is very sensitive to its water management. If no proper land treatment has been met, the soil will be damaged by erosion, flood, and salt accumulation. Man made desertification is apt to progress easily by ill-water-management, since the rainfall in dry land is usually unpredictable.

The run-off agriculture is a method of making best of natural conditions to collect the rain for irrigation. By this method, almond, olive, pistachio, peach, vine, sorghum, wheat, barley and fodder can be cultivated. Even fire wood is being produced. This method is a system to catch, collect, store the rain and to make its timely use for irrigation. The irrigation system with high technical devices for soil moisture control is ready for dry land reclamation.

The collecting methods of the run-off agriculture are classified into 5 main types.

a. Conduit channel type

This is a method to catch the rain water running down to a narrow canal set along the contour lines of mountain side. A large amount of water is stored by a shallow earth dam surrounded by small levees. A case in the desert where an annual rainfall is about 100 mm shows that 20 times water catchment in the area is calculated to keep 1 area.

b. Diversion type

In a strong rainfall the water is attracted into Wadi to make easily flooded

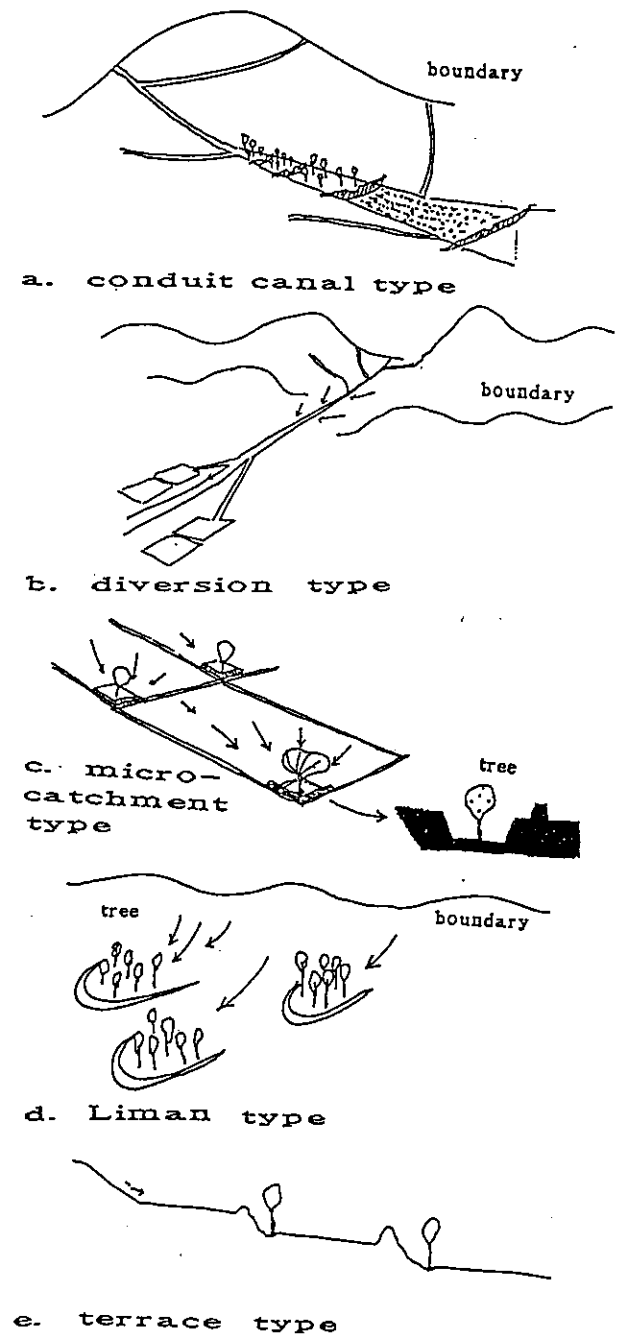

Figure 2 Pive types of water collections

places where impermeable layers or unweathered rocks can be found under the surface soil. This flood is conducted to diversion canals for irrigation. Some of them are connected to cisterns or underground dams through conduits.

c. Micro catchment type

A square lot like a paddy field (*e.g.* 10m x 10m) is used for the water collector to irrigate a tree planted in the lowest place of the lot.

d. Liman type

A horse-shoes-shaped-dam in plan view of which mouth opens to the mountain side is constructed in the river bed in Wadi. Trees are planted in the inside of dam. This type is a mini-copy of micro-catchment type.

e. Terrace type

The rate of water on sloping land can be decreased by terrace works. The smaller the catchment area, the steeper the slope of catchment is required for the high efficiency of water harvest because the water loss during running down must be minimized. It is necessary that the water runs quickly on sloping surface without percolating into the soil. The optimum range of slope without erosion is between 0 to 10% (less than 5.7°. This type of water collecting system is found in North America, Mexico, and Pakistan.

For example, terraces are constructed at the height of every 1.5 m on a 30° slope coated by impermeable layer. Trees are planted on each terrace. The tree can grow in good condition by the run-off harvest. It is reported that the 3 years old trees is improved by 60% up in wood production as compared with the case of the non-treated one.

These 5 types of collecting devices are constructed according to geographic and topographic conditions. The most popular agricultural land use is for the crop cultivation.

Orchard tree and fodder grass can grow in the micro-catchment system. Olive and vine are often cultivated in the liman system. It is reported that the mean annual rainfall of 115 mm is able to produce the 40 kg of olive fruits for one tree using the system while olive trees generally needs water of 600 to 800 mm annually for the same result.

The actual catchment area is better designed larger than that of planned irrigation area. In some cases, the endurable asphalt coating or paraffin coating of soil surface improves the efficiency of water collection. In the dry land in USA, they use glass fiber on which molt asphalt is poured in to make a tight impermeable surface.

In Israel, the greening of cities is make by the plantation of various trees and flowers in association at the parks and in the

street green belt, that is, eucalyptuses, date palm trees, olive trees, cypress trees, and many flowers are taken care by drip irrigation. The soil moisture control for avoiding of salinization is led by drip irrigation.

In some place, the water is conveyed to reservoir from which irrigation water is distributed to the citrus orchard on sloping land. The reservoir is constructed in place with impermeable layer.

The study of land use in dry land is being carried out in the Desert Research Station, Ben-Gurion University, located in the Negev in Israel. One of them is to make a systematic land use for agro-forestry with fodder and field crops.

The system will be available even in places where the annual rain fall is between 100 and 200 mm. The collected surface water is absorbed in the void of soil structure and is available for irrigation water in the dry season. This system produces biomass from the litter in the woods. We can expect that the agro-forestry system consumes efficiently the water because water will be retained in layers with small loss. The water in shallow layer is taken up by annual crop roots, while the water in sub-surface layer is taken into the root zone in sub-surface layers. Crops with shallow roots zone and trees with long roots are planted systematically in alley so that the rain water stored in layers will be consumed efficiently by both crops and trees. This cultivating of grain and woods during the same period is a good example of agro-forestry system.

It is reported that acasia and eucalyptus are cultivated in different planting density in Table 2 and found that if the dry weight of both trees are compared after 3 years cultivation, there are no big differences between their yields, and that the water in upper layers and lower ones show the different movement in water-taking up by both plants. The most important condition for trees growing is that the roots are penetrating enough in deep layers. From these results the multilateral cultivation of crops with trees is possible in the same field (Berliner, 1990).

The moisture distributed in surface layers will be consumed by annual crops.

Table 2 Dry weight of the upper part of tree from the ground after 3 years cultivation (ton/ha).

Density of planting (number of trees/ha)	acacia	eucalyptus
625	15	25
1250	19	28

The tree with roots penetrate to the layer deeper than 2 m are able to grow in dry condition and very resistant to the drought because the trees can take the water from sub-soil. If we can make enough soil moisture to plant growth by the run-off water, the possibility of land use would increase in the dry land having a wider water catchment.

The ancient canal system (more than 3000 years old) is still existing in Avdat in the Negev, Israel. There we can see the wisdom of the ancient to collect the water for irrigation. Here the energy flow and material transport system, and the close connection between the formation of ecosystem and the mechanisms of soil production are being observed by the university. This run-off water harvest which offers the possible method for creating a stable ecosystem will greatly depend on the water Katena system.

A trial to recover the natural ecosystem balanced with agricultural production system has been done by introducing the agro-forestry in dry lands.

2. Semi-humid and humid region

There are two types of land-use in the agro-forestry system. One is (a) rotational land use. For example, a forest is changed to farm-land by cleaning and then it is changed to the forest again. The other is (b) the mixed land use of forest with farm land, which is used as agricultural fields for several years after agroforestation. These types of land use is very common in the tropical rain forestry region.

Annual and perennial plants are often chosen in combination with trees. Paddy, maize, pulse and vegetable are classified as plants for the annual. Cocoa, rubber, oil palm and banana belong to the perennial. These crops are cultivated in the younger stage of forest growing. The cultivation of crops is selected according to the growing stage of trees.

Land use types (a), (b) are often found in the mixture of both types. There are many varieties of land use on sloping land. Some crops need shiny places, but some don't so that the canopy of these trees will make a nice shadow for the other crops in process of tree growing. In some cases densely planted trees can protect crops from strong wind.

In the tropical rain forest the space is well allocated by the mixture of lofty tree, medium tree, short tree in height. The forage and litter in the forest can be used for fodder. The combination of forest land use and cattle pasturing will supply the manure to assist trees growing.

From an agricultural view point, we can see the agro-forestry system to contain in following strong points.

a) The fluctuation of crop yields is small and stable.

b) The solar energy can be used efficiently, eliminating the overlapping of leaves.
c) Litter supplies the organic materials to the soil as well as to improve the soil water retention capacity so as to retard the water run off.
d) Soil surface erosion by rain fall will be prevented effectively, because all the year round many varieties of crops and trees are cultivated.

In South East Asia, many kinds of trees are often cultivated in the inside of villages for fire wood. For example, in the outskirts of Jokyakarta there are many settlements covered by woods and surrounded by forest.

Another example can be seen in a modernized socio-agro-forestry in Malan, Indonesia. There we can see the tie-up system of agro-forestry with social benefits. In this case land use has a system in which forestry land is linked with crop production and soil conservation in cooperation with farmers living in the settlement.

Japanese land-use for agro-forestry

Japanís agro-forestry system existed in the old traditional way that buckwheat, hemps and soybean were cultivated after firing a bush in order to make the forest of cider. The main aim of this system is not for the cultivation of crops but for forest.

Rice production leads the Japanese agriculture. Paddy cultivation depends on the water supply from the river of forest origin. The Japanese land use for agricultural production system is a real agro-forestry because forest is functioning as a water reservoir for paddy fields. At the same time paddy fields are preventing the forest and villages from land slides and flood disasters.

The reclamation of upland in Kanto Plain including Tokyo started in 1600's. The reclamation at that time showed one of land use planning in which the complex of forest, agricultural field and village settlement was designed as a single system. That is, they allotted the alluvial place for paddy fields, upland fields and woods to get firewood and litters. They made the recycle of litter from woods to the field to keep its fertility. Manure made from litter and sewage were supplied during winter or spring to enrich the soil. Many villages or settlements consisted of those interdepending land use.

It was generally recognized that the forest was necessary for the people living in settlements for their agricultural production and their daily life. Seeing a view from agricultural production, the forest was used as one of water conservation facilities and a source of supply of organic materials, at the same time functioning as one of links of material re-cycling. This is a reason why

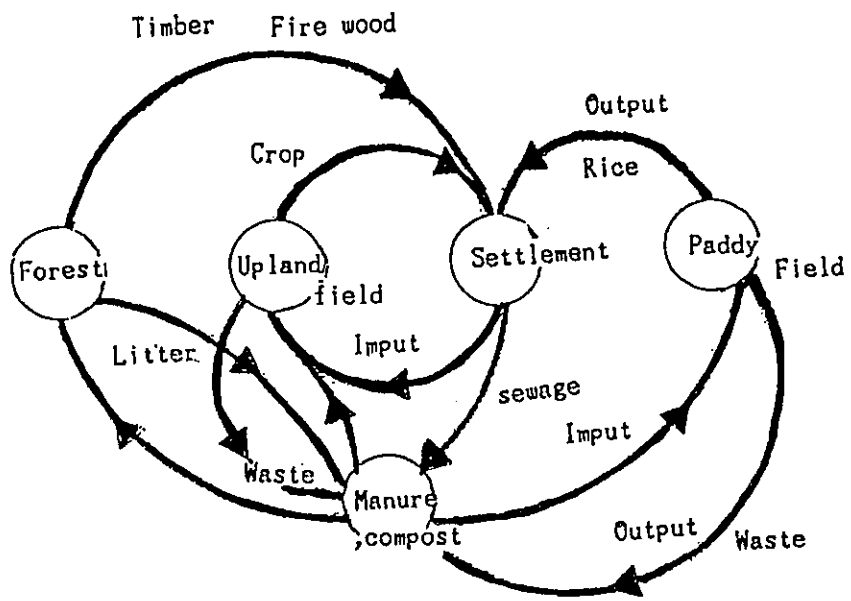

Figure 3 A recycle system of organic matter in old Japanese agriculture.

the agro-forestry has existed traditionally in the Japan's land use of agriculture.

After the World War II the forestation in Japan was carried out for the production of timber and pulp. Afforestated trees were mainly conifers which will be harvested after 30 to 40 years for timbers. These trees have not cultivated enough to resist against heavy storm in Japan. Instead, broad-leaf trees are wild and strong and are useful as wind breaker. These trees will produce a lot of humus which can hold much ground water. The soil under the forest of beech purifies the acid rain. The mixture of beech and cider woods will be useful for the environmental protection and water conservation. Land use planning must be proceeded in accordance with the natural link of material flow system.

The sustainable agriculture could not be realized without the combination of water flow chains and re-cycle system of organic materials. In Japan we can find that the modernized agro-forestry system with comprehensive land use is giving a good result for sustainable agriculture.

An example can be found in the northern district of Japan where they try to plant the broad leaf trees on the mountain slope in stead of conifers for the water conservation. This afforestation movement of the broad leaf trees is being developed from the tie-up for soil and water conservation between the farmer of up-stream and the fisher-men of down stream because the

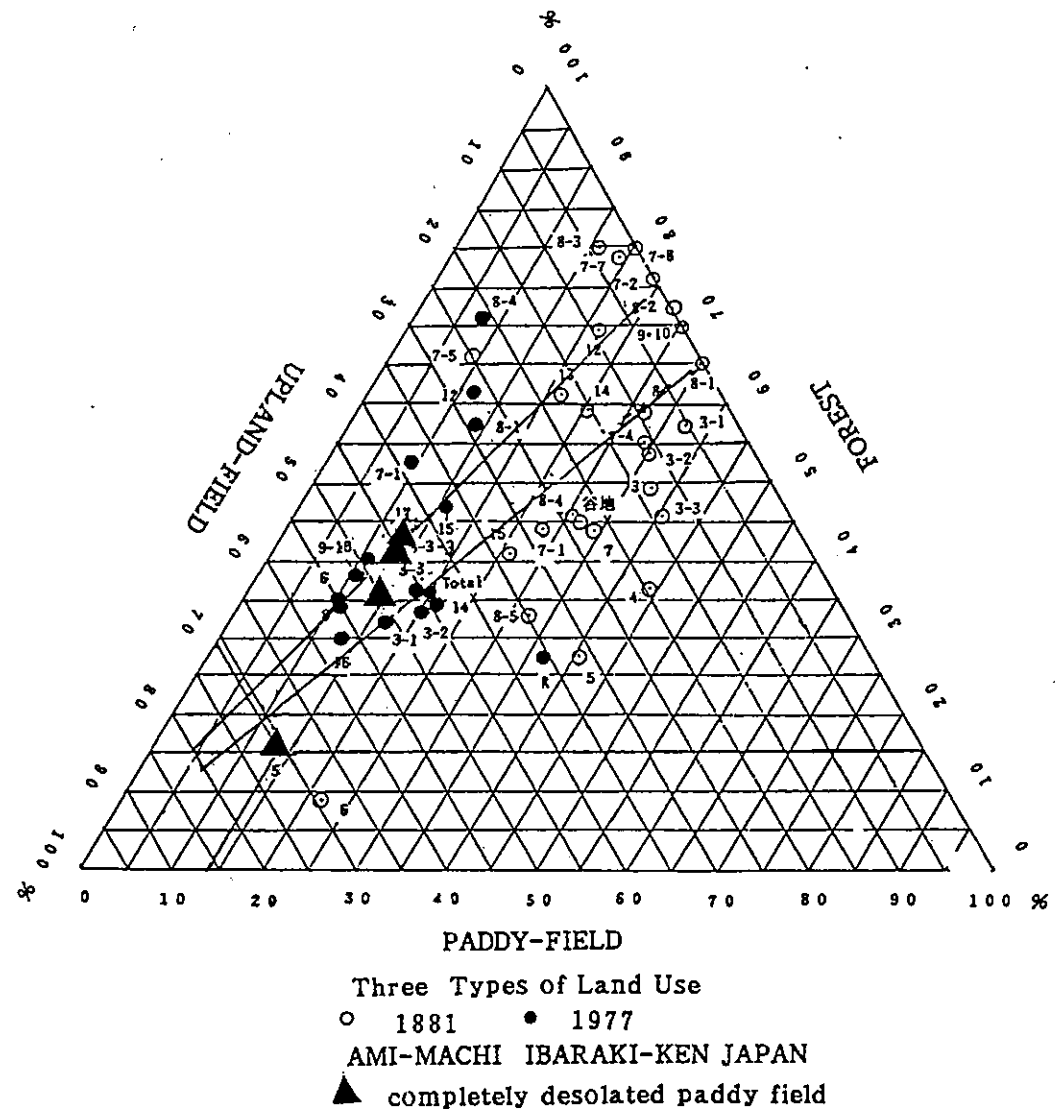

Figure 4 Triangle for % distribution of forest, paddy field, and upland field (in Japan).

clean sea water is very important for maintaining high quality shell fish. The afforestation helps farmers in the water shed area not to suffer from water shortage. They were able to get enough water even in 1994 summer drought. The land use suitable for its environmental characteristics is the common technique to make a good circumstance.

RESULTS AND DISCUSSION

Agriculture has always developed to get more productive so as to result in the environmental devastation coming from our ignorance of combination between agricultural and forestry land-use. The wood on sloping field is useful to prevent the soil from erosion. Particularly on sloping land in the tropical rain forest region, these mixed land use between forest and agricultural field, that is the agro-forestry will make the production compatible at the same time with the conservation.

Dry land could be reclamated by making forest, agricultural field and settlements in which they can manage their land use properly taking account of the water environment, that is, the KATENA of water-flow from the top of high land to the bottom of alluvial plain. The minimum requirement in each dimension of land use can be decided using the calculation of the amount of organic materials supplied to each field on the process of re-cycle system.

What proportion of land use in a water shed will be necessary between upland field, lowland field, forest and settlement? A ratio between three types of land use may be given in each region. A case study done in Kanto district shows us a ratio between paddy field, upland field and forest to be 2:4:4.

The wider sense of agro-forestry will give us an answer for the method of land allocation in regional planning. This method will still be useful now-a-days to make a rural planning not only in Japan but also tropical humid regions and arid regions as well. The agro-forestry will offer the answer to establish a possible sustainable agriculture.

I propose a multi-lateral land-use for the sustainable agriculture in humid regions will be created on the basis of the Katema. Intensive agriculture should be taken care of the material re-cycle system as was seen in Japanese ancient agriculture. This type of agricultural land use can be called socio-agro-forestry system as is seen in Malan in Indonesia.

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