# PROBLEMS OF LAND USE IN UPLAND SOUTHEAST ASIA[1]

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Southeast Asia is characterized by very great ecological and social diversity. The contrasts between the lowlands and the upland areas within the region are particularly striking (Rambo and Sajise 1985). The lowlands, made up of broad alluvial deltas, riverine valleys, and coastal plains, are the economic and political core areas of the region's nations. Although covering less than one-third of the surface area, they contain more than two-thirds of the population and probably account for more than 90 percent of the national income of most Southeast Asian states. These are areas of very dense population, well developed wet rice agriculture, and strong government. Each of these core areas displays considerable homogeneity whether looked at in terms of social organization, ethnicity, or agroecology. Their systems of agrarian land use, based on wet rice cultivation, are highly intensive, extremely productive, and relatively sustainable. For example, the Red River Delta of Vietnam has supported a very dense peasant population for at least one thousand years.

In contrast to the homogeneity of the lowlands, the uplands of Southeast Asia are distinguished by their ecological and ethnological diversity and consequent great diversity in patterns of land use. Land forms include the jagged limestone karst topography of Hoa Binh Province in northern Vietnam, the undulating peneplain of the Khorat Plateau in northeastern Thailand, the steep granitic slopes of the high mountains of northern Laos and the Cordillera of the Philippines, and the conic volcanoes of Java with their rich basaltic soils. Topographic and edaphic variability are matched or exceeded by that of climate, hydrological regime, and biological endowment. The level of biological diversity, including that of domesticated plants and animals, in the uplands is remarkable, especially in contrast to the extremely low diversity of the intensively cultivated lowlands (Le Trong Cuc and Rambo 1993).

Ecological diversity is matched or exceeded by the diversity of upland social and cultural systems. Vietnam alone, for example, has 54 distinct ethnic groups of which 50 live primarily in upland areas. Peninsular Malaysia has some 20 distinct ethnic groups, again with most living in mountainous areas. Each group is characterized by its own patterns of social and economic organization, each has a unique form of adaptation to the upland environment, each employs different methods of land use having specific consequences for sustainability. In recent years, diversity has been further enhanced by expansion of the market system, introduction of new crops and productive technologies, and in-migration of settlers from lowland areas. Thus, while it has been a commonplace in the ethnological literature to describe land use in Southeast Asia in terms of a simple dichotomy between tribal peoples practicing swidden agriculture on the steep slopes of forested mountains and wet rice growing peasants in the lowlands (Burling 1965), the reality is far more complex. It is possible to offer a single summary description of the agricultural ecology of the lowlands, but the diversity of the uplands can not be captured in terms of a single categorization. Instead, it is necessary to write in terms of a variety of different patterns of land use, each with its own social and ecological characteristics and consequent environmental problems. As a consequence of this diversity, no single strategy of development, no single model for resource management, no single system of land use can be successfully applied to the uplands as a region. Instead, agricultural research and development must itself be diversified, employing a variety of methods to generate a wide range of technologies and

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management strategies applicable to the great diversity of local agroecological situations (Rambo and Sajise 1985).

## 1. Some Different Patterns of Land Use in Upland Southeast Asia

Ideally, it would be possible to organize this paper in terms of a comprehensive typology of the multitude of distinctive forms of land use in Southeast Asia's uplands. Unfortunately, existing information is inadequate to construct such a classification. Instead, in this paper I will describe four distinctive forms of land use that are found widely distributed in many parts of the uplands. These types are (1) irrigated wet rice system, (2) rain-fed wet rice system, (3) rotational swidden system, and (4) composite swidden system. Reflecting my own research experience, illustrative examples will be drawn from mainland Southeast Asia, including Laos, Thailand, and Vietnam. Table 1 presents a summary description of these upland agroecosystems with regards to their performance in terms of the system properties of productivity, equitability, diversity, and sustainability.

## 2. Irrigated Wet Rice System (Chiang Mai Valley, Thailand)[3]

In many parts of Southeast Asia's uplands where topographical and hydrological conditions are favorable, farmers have constructed irrigated wet rice fields. Examples of this type of agroecosystem are found in the highlands of western Java, the Cordillera in the Philippines, and the Chiang Mai Valley in northern Thailand.

The Chiang Mai Valley is one of a number of large intermontane basins in the mountain zone of northern Southeast Asia. Many of these basins, of which Dien Bien Phu is perhaps the most famous, are inhabited by T'ai speaking peoples. Historically, these basins have been the core areas for independent feudal principalities or statelets. The Chiang Mai Valley was home of the independent kingdom of Lana until it was absorbed into the central Thai kingdom in the 19th century.

For some hundreds of years northern Thai peasant farmers have engaged in cultivation of wet rice in small bunded fields irrigated by gravity flow systems. As the rural population has grown and the average size of farm plots declines, farmers have intensified their cultivation. Today, three crops are grown per year, two of rice and one of vegetables. Yields are high reaching more than 7 tons/ha/yr.

Inadequate supply of irrigation water is the major constraint on productivity. The irrigation system is managed by the state and is not always responsive to the needs of the farmers for water at appropriate times.

Equitability was formerly relatively high but has declined in recent years as land prices have increased.

Crop diversity is relatively high with more than 30 locally adapted rice varieties still regularly cultivated. Farmers have retained these lower yielding varieties because they fit the very specific agroecological conditions of the valley.

Under traditional methods of cultivation, the system was highly sustainable. Heavy use of manure and other organic inputs maintained soil fertility. With intensification of production, farmers began to employ chemical fertilizers but recently long-term decline in productivity has been observed, reflecting the insufficiency of micronutrients, principally boron, in the over-exploited soil of the paddies. Pest problems have also grown more severe as cropping intensity has increased. The growth of Chiang Mai City as a major administrative, commercial, and

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3 This section is largely based on Multiple Cropping Project 1980 and Rerkasem and Shinawatra 1988.

tourism center has led to urban sprawl and conversion of much good farm land into homelots for city people.

### 3. Rain-Fed Wet Rice System (Khorat Plateau, Thailand)[4]

The vast Khorat Plateau of northeastern Thailand is an undulating plain broken into a multitude of mini-watersheds. Because of low rainfall, high rates of evaporation, and porous soils, surface water supplies are scarce and irrigation possible only in a few favored river valleys. The majority of the farmers of the northeastern region must rely on natural precipitation to supply water to the paddy fields where they raise a single crop of glutinous rice for subsistence use.

Rainfall in the northeast is extremely irregular, however. Rain tends to come at the wrong time and in the wrong amount so that there is either drought or flood or, in particularly bad years, both. Farmers are lucky to raise 2 good crops in 5 or 6 years. As a result, agriculture is extensive with each household farming several hectares in the hope that they can produce enough rice in each good year to meet their needs for the several bad years that are sure to follow. Traditionally, farmers relied heavily on wild foods from the forested hills to supplement their daily diet and as emergency stocks during years when the rice crop failed. In recent decades farmers have cleared large areas of forest to plant cassava and kenaf to earn cash income. This has lowered biodiversity and dramatically reduced supplies of wild foods.

Productivity is low, even in good years, averaging under 2 tons/ha. Soils are very sandy with low inherent fertility but farmers rarely apply chemical fertilizer. This reflects the fact that rice is a subsistence crop but fertilizer must be purchased with cash. Since crops fail in many years farmers fear going into debt if they invest in purchased inputs.

Under traditional management practices the system is quite sustainable. Because productivity is so low removal of nutrients occurs slowly although there is long-term decline in fertility levels. In some areas salt beds lie close to the surface and salinization is reducing yields or even forcing abandonment of fields. Out-migration of young people to work as laborers in Bangkok or even the Middle East is perhaps the greatest threat to the sustainability of the system, however. With the closing of the land frontier in the northeast, new households can not obtain large enough plots on which to survive so are forced to emigrate in search of employment elsewhere.

### 4. Rotational Swidden System (Sepone District, Laos)[5]

Swidden agriculture (also known as slash-and-burn or shifting cultivation) is the most widespread form of agricultural land use in the uplands of Southeast Asia. Although this system was productive and sustainable under conditions of low population density and abundant forest resources, it is much less so today. Indeed, it is fair to say that there is a major crisis facing swidden farmers throughout the region. Nowhere is this more evident than in Sepone District, Savannakhet Province, in southern Laos.

A number of villages of Lao Theung belonging to the Tri ethnic minority are found in the mountains along National Road No. 9 near the border of Laos and Vietnam. Subsistence cultivation of hill rice in swidden fields is the major economic activity in these villages. Soils are thin, highly acidic, and poor in nutrients and organic matter. Although the area was formerly covered with primary forest, it was largely destroyed with herbicides during the war. Wild fires

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4 This section is largely based on KKU-Ford Cropping Systems Project 1982, Rambo 1991, and Fukui 1993.

5 This section is based on SUAN Secretariat 1991.

and extensive swiddening have prevented significant regeneration so that large areas are now covered with bamboo, scrub, and grasses.

The typical Lao Theung household exploits an agroecosystem composed of swiddens, a home garden, livestock, and secondary forest. Recently, a few households have begun to construct rudimentary wet rice fields but these are not yet as important. It is the swiddens that supply the bulk of grain consumed by the villagers.

Swiddens are the dominant component in the agroecosystem. Two types of swiddens can be distinguished: Fields cleared in bamboo or scrub brush vegetation in the lowlying area near the village and fields cleared in secondary forest on steep hillslopes some distance from the settlement.

The swiddens are not very diverse and are primarily monocultural rice. Only a few varieties of upland rice are used, one short duration and the other longer duration. Only one variety is typically planted in small swiddens, whereas in large fields, both varieties are used to stretch out the harvest period. Upland swiddens display considerably greater number of species than those close to the village. There are also greater numbers of secondary crops in upland swiddens. In upland fields, intercropping with maize and cassava is somewhat more common but is still subject to predation by wild pigs and monkeys which eat maize and cassava. Those swiddens near villages, e.g. bamboo forest areas, have little corn intercropping because goats eat maize and cassava.

The swidden cycle begins in late February when the site for the new field is selected. Vegetation is cut using long blade knives and axes. The cut vegetation is allowed to dry for approximately one month after which it is burned. Farmers recognize that ash provides fertilizer. One farmer reported, however, that a large concentration of ashes can damage rice seedlings because the soil is too "salty." A good rain following the burn will usually solve this problem. Farmers also recognize that fire kills weeds. Bamboo burns well with a good hot fire. Some hardwoods in the secondary growth uplands burn to charcoal rather than ash and are better cut for house construction.

The newly burned swidden fields are planted using dibble sticks in May. During the growing period, the field is weeded three times, the first time in June, with the last weeding done at the time of the rice flowering in September. The rice is harvested in October. Productivity is very low ranging from 150 to 600 kg of paddy per hectare per crop. Consequently, most households are unable to produce enough rice to meet their consumption needs. They report suffering shortfalls for 3 to 6 or more months per year.

Animals are the biggest constraint on swidden productivity. In swiddens near the villages, goats eat corn and cassava so that people do not bother to plant many secondary crops. In upland fields, wild pigs and monkeys are a major problem. Trapping is the main defense because guns are few and ammunition is scarce. Some farmers also build fences to keep goats and wild pigs out of fields. Birds, rats, toads, and lizards are said to eat the seed at planting time, but farmers have no effective response. Pigeons, small parrots, and wild chickens eat the rice at harvest time and people stay in the fields to protect the grain. Insect pests of rice include caterpillars and grasshoppers. The seriousness of the insect pest problem varies from field to field.

Weeds are a major constraint on productivity, requiring very heavy investment of labor to control. The shortness of the rotation and the consequent lack of sufficient biomass to ensure a good burn has led to increasing infestation of weeds. Bamboo regrowth and regenerating trees are almost impossible to control during the second year of cultivation. Weeding is done by hand, using knives and chopping blades on the end of digging sticks to cut weeds. Once cut, the weeds are left on the swidden surface as compost.

Climatic factors also take a heavy toll on the rice crop. In 1990 flooding destroyed much of the rice crop in lowland swiddens. In 1988, a drought reduced the crop. A few years earlier, a heavy wind destroyed crops. In some cases, war damage continues to be a constraint. Bomb craters reduce the potential area for planting. Farmers do plant the crater slopes and bottom but the crop at the bottom is at risk from flooding. The outer rim of the crater is not productive because it is compacted subsoil (red soil) thrown out by the explosion. Fear of unexploded bomblets in fields makes people work very slowly and carefully when clearing. Burning of fields is useful in that it explodes some bombs and makes those remaining on the surface more visible.

## 5. Composite Swidden System (Da River Watershed, Vietnam)[6]

The Tay minority people of Da Bac District in Hoa Binh Province in northern Vietnam employ an adaptive strategy that I will refer to as "composite swiddening." The defining characteristic of composite swiddening is that households simultaneously manage both permanent wet rice fields in the valley bottoms, shifting swidden fields on the hillslopes, and exploit wild resources of the forest. Home gardens, fish ponds, tree gardens, and livestock are also part of this very complex type of land use. Similar composite systems are found among the Muong of northern Vietnam, the Shan of Burma and northern Thailand, the Hani of Xishuangbanna Prefecture in Southwestern China, and the Ifugao of the Cordillera in the Philippines.

The distinctive characteristic of this system is that swiddening comprises an integral component of the adaptation. It is not a gradually vanishing survival of an earlier, more primitive pure swiddening adaptation that is the process of being replaced by more advanced irrigated farming. Neither is it a recent response to rapid population growth that has exceeded the carrying capacity of the wet rice fields and forced people to expand their farming onto the forested slopes. Instead, composite swiddeners such as the Tay have practiced both wet rice farming and swidden agriculture together as an integrated system of subsistence for a very long time, certainly for generations and probably for centuries. Paddies are generally believed to be more productive if they receive sufficient manure. But the Tay plant swiddens because they serve as a buffer against the risk of crop failure in the paddies while broadening the range of subsistence resources.

The typical Tay household manages a complex agroecosystem (Fig.1). Key subsystems include wet rice fields, home garden, fish pond, livestock, tree gardens, rice swiddens, and cassava swiddens. Fallow swiddens and secondary forest are also exploited but management of these land units is the responsibility of the cooperative.

### Wet rice fields

The wet rice fields are built in a series of terraces rising like steps from the stream in the middle of the valley floor. Each terrace is quite small, covering an area of 30 to 70 $m^2$. Irrigation water enters the highest terraces from small streams flowing down the hillslopes and spills down from the upper fields to the bottom level where excess water flows into the large stream running through the floor of the valley. The flow of water through the paddies is continuous.

Because the fields are kept continuously flooded, plowing is not required. Cultivation is done by buffalo-drawn harrows. Each field is harrowed 3 times before planting. As many as 6 buffalo will be used at once in the larger fields. Farmers from several households exchange their own labor and that of their buffalo to do this task. After the final harrowing, the rice seedlings are immediately transplanted by groups of women. The planting pattern is quite casual with little concern shown with placing the seedlings in straight rows.

6 This section is based on unpublished research by the author and Le Trong Cuc of Hanoi University.

Manure from the buffalo and cattle, night soil, and green manure are all used to fertilize the paddies. Recently, some farmers have begun experimenting with the use of chemical fertilizers. Manure is collected from the buffalo and cattle that are stabled at night underneath the house. It is stored in large woven bamboo bins until needed and then carried to the fields in pack baskets by the women and children and with shoulder pole baskets by the men. One farmer said that he used 300 kg of manure per crop for a field area of about 1,500 $m^2$. He said that this was a higher than average amount because his fields were close to his house. Farmers say that they generally have adequate quantities of manure and that use of greater amounts would produce excessive vegetative growth with lowered grain production.

Most farmers grow improved varieties of non-glutinous rice in the spring crop and traditional varieties of glutinous rice in the summer crop. One farmer said that they preferred non-glutinous rice because a small amount of grain cooks up into a large volume of rice. Yields are quite low, averaging around 2.5 tons per hectare per crop. Because plots are so small, averaging 0.14 ha per household, families harvest an average of only 650 kg of paddy per year. This is an insufficient quantity to meet their grain needs so they must make up the shortfall by cultivating swiddens.

Swiddens

The Tay distinguish between two types of swiddens, those for cassava and those for rice. The cassava swiddens are sited on the lower slopes of hills near the hamlet where the soil is too sandy and infertile to support rice cultivation. Two varieties of cassava are grown, one with dense broad leaves and the other (banana cassava) with thin leaves. The broad leaved variety is by far the most common although farmers say that the banana cassava has a better taste. Cassava roots are eaten as a substitute for rice. The roots are also fed to pigs and the leaves used for carp food. Fresh roots and dried chips are sold to the government.

Rice swiddens are cleared when possible from secondary forest on soils thought to be of higher fertility. The Tay judge the fertility of swidden soil by sticking a knife into it. If soil sticks to the blade when it is pulled out, they consider the soil suitable for rice. If nothing sticks, it is only good for cassava.

The Tay swiddens display a low diversity of crop species. Some rice swiddens are almost pure monocultures. One quite large field located about 1 km from the hamlet was planted with 4 varieties of rice. The only other crop was some sesame which was planted scattered in a thin line along the bottom of the field. Swiddens located at a greater distance from the settlement are characterized by somewhat greater crop diversity. They may have cucurbits, squash and melons, rice beans (yard long beans), and sometimes a few maize plants intercropped with the rice. Most of these plants are grown for consumption on the spot when the Tay stay overnight in their field huts to protect their ripening crop from wild animals. Surplus production may be carried back to the village for consumption there. None of the Tay swiddens approximate the diverse polycultural swiddens of Geertz's ideal type, however. Certainly their architecture does not mimic the tropical rainforest with multiple layers of canopy. Instead they resemble a field of tall grass, except that they are much more open with considerable areas of soil exposed.

Most households cultivate at least two rice swidden plots at any one time. The average area cultivated each year is about 1.2 ha. Yields are estimated to average 680 kg/ha. Yields have been declining, however, because of the shortening of the fallow period from 10 years to as short a time as 3 or 4 years. In several actively cultivated swiddens, Melia seedlings were observed growing scattered among the rice plants. In some cases these plants are volunteers, with seeds probably dispersed by birds. In other cases they are deliberately planted. The seeds are dibbled into the field before burning so that the fire will cause germination. Melia and candlenut are also planted in the cassava swiddens. Few other trees were observed in the swiddens and no attempt appears to be made to protect coppicing stumps or to enrich the fallow with more trees than occur naturally.

Following the rice harvest, swiddens become open access pasture for cattle and buffalo from the hamlet. The effect of grazing on regeneration of secondary forest has not yet been studied. Several Tay remarked that efforts to improve management of the fallow period such as enrichment planting of leguminous trees would be made difficult by unregulated grazing. Finding ways to accelerate the rate of regeneration of fallow swiddens is one of the most critical problems facing composite swiddeners.

Home gardens

Scattered around the house plot are a variety of trees that make up the home garden. Papaya, bananas, pomelo, oranges, guava, and jackfruit are the most commonly planted species although no house has more than 2 or 3 individuals of any one species. Clumps of tea plants and a shrub, the leaves of which are used to make soup, are more numerous. Some houses also have a small bamboo-fenced enclosure where green vegetables are grown protected from depredations of the free-ranging household livestock. Green onions are sometimes planted in raised wooden troughs. Marigolds and other ornamental flowers are sometimes also grown in the home garden.

Fish ponds

Located within a few meters of most houses are one or more small fish ponds with an average surface area of about 100 $m^2$ and a depth of from 1 to 2 m. The ponds are filled with water flowing through bamboo pipe conduits from streams or springs on the hillslopes behind the house site. Carp of several species and tilapia are the most commonly raised fish. They are fed cassava leaves, weeds, rice bran, and buffalo and pig manure. Cultivation is not very intensive.

Livestock

Most households have at least one buffalo and several cattle. In some cases they are grazed in the swiddens after harvest. Most are allowed to range freely in a valley that is reserved by the cooperative for use as a pasture. Goats were raised some years ago but were abandoned because of the destruction of vegetation that they caused. Pigs of the local pot-bellied variety are kept in small numbers but are said to be vulnerable to disease. Pigs are of great ritual importance as they are needed by the families of young men for bride payments. Some are free ranging during the day while others are kept all of the time in small cages in the home gardens. They are fed cassava roots from the swiddens close to the village.

A small number of chickens are kept by most households for feasts and for eggs. Ducks are also raised. Fowl range freely around the houses during the day but are kept in special bamboo pens beside the house at night.

Tree gardens

Planted on the hill slope behind the house are patches of planted trees. Palms, Melia, Aleurites montana (candlenut), and bamboo are the most common tree garden species, usually planted in pure stands. Few of the Aleurites trees bear nuts because of failure to select only female plants. Melia and Aleurites are also planted in cassava swiddens where they gradually become the dominant species. Recently, people have also begun planting Eucalyptus in old cassava swiddens as part of a PAM (World Food Program) reforestation effort.

## 6. Conclusions

The diversity of types of land use in the uplands of Southeast Asia is quite remarkable, belying the stereotype that the entire area is inhabited by nomadic shifting cultivators. Existing systems of land use are often complex and well adapted to the environmental conditions of the

uplands. It is only in the face of increasing population pressure and heightened demand for resources that the sustainability of these systems is threatened.

Irrigated and rain-fed wet rice systems are both highly sustainable until efforts are made to intensify productivity. These systems are well served already by existing agricultural research agencies, however, so they are not an urgent priority for further research. Rotational swidden systems are the most vulnerable type of land use in the uplands. They are everywhere breaking down as growing population pressure and loss of access to forest lands forces shortening of the fallow cycle below sustainable levels. Development of alternative systems of resource management to replace rotational swiddening is the most urgent task confronting land use researchers in Southeast Asia. Ironically, rotational swiddening, although practiced by many million people, has received the least share of attention from international and national agricultural research agencies. Only very belatedly has the International Centre for Research in Agroforestry (ICRAF), with support from the Global Environmental Facility, launched its research initiative on sustainable alternatives to slash-and-burn agriculture. A much greater effort than that proposed by this initiative is needed, however. Composite swidden systems are of particular interest because they may offer useful models for replacing pure rotational swiddening. But research has only just begun on this unique type of agroecosystem.

Table 1: SOME LAND USE SYSTEMS IN UPLAND SOUTHEAST ASIA

| Site | CHIANG MAI VALLEY THAILAND | KHORAT PLATEAU THAILAND | DA RIVER WATERSHED VIETNAM | SEPONE DISTRICT LAOS |
|---|---|---|---|---|
| Agro-ecosystem type | irrigated wet rice system | rain-fed wet rice system | composite swidden system | rotational swidden system |
| Land form | Intermontane basin 300m asl | peneplain 200 m asl | mountains and valleys 500-950 m asl | mountain slopes |
| Terrain | flat | undulating "mini-watersheds" | steep (40°- 60°) mountain slopes and narrow valleys | broken terrain with slopes 20°-60° |
| Soil type | alluvial clay | highly weathered, sandy loam and loamy sand | hill complexes and alluvial clay | hill complexes with thin topsoil |
| Soil fertility | moderate | very low | low-moderate | low acid |
| Natural vegetation | none remaining | open dry dipterocarp forest | evergreen rain forest | evergreen rain forest |
| Population density | >600/km$^2$ | <100/km$^2$ | <200/km$^2$ | <25km$^2$ |
| Ethnic composition | Northern Thai | Thai-Lao (Isan) | Tay, Muong | Lao Theung |
| Rice yield | 4-7t/ha/year (2 crops) | 1.2-1.8t/ha/ year (1 crop) | paddies: 5t/ha/ year (2 crops)<br><br>swidden: 680kg/ha/ year | 150-600 kg/ha/year |
| Limiting factors on productivity | • water,<br>• soil fertility<br>• labor | • water,<br>• soil fertility<br>• labor | •transportation and market access<br>• soil fertility<br>• weed infestation | • weed infestation<br>• labor<br>• soil fertility<br>• water<br>•transport-ation |
| Hazards to productivity | • unstable prices<br>• floods<br>• drought<br>• crop pests and disease<br>• urban sprawl | • drought<br>• flood<br>• unstable prices | • drought<br>• cold weather | • drought<br>• wild animal pests<br>• storms<br>• human disease<br>• unexploded bombs |
| Equitability | low | medium | high | high |
| Biological diversity | low | low | high | medium |

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|---|---|---|---|---|
| Threats to diversity | • replacement of traditional land races by HYVs | • deforestation | • deforestation<br>• replacement of traditional land races by HYVs<br>• over-exploitation of wild species | •deforestation<br>• overgrazing |
| Sustain-ability of land use | high but declining | medium | medium but declining | low |
| Threats to sustain-ability of land use | • declining soil fertility (depletion of micro nutrients)<br>• inflation of land prices | • declining soil fertility<br>• soil erosion<br>• salinization<br>• out-migration of laborers | • soil erosion<br>• declining fallow period<br>• rapid population growth | • soil erosion<br>• declining fallow period<br>• degradation of forest and shift to grass land succession<br>• rapid population growth |
| Opportunity for intensi-fication | low | low | moderate | high |

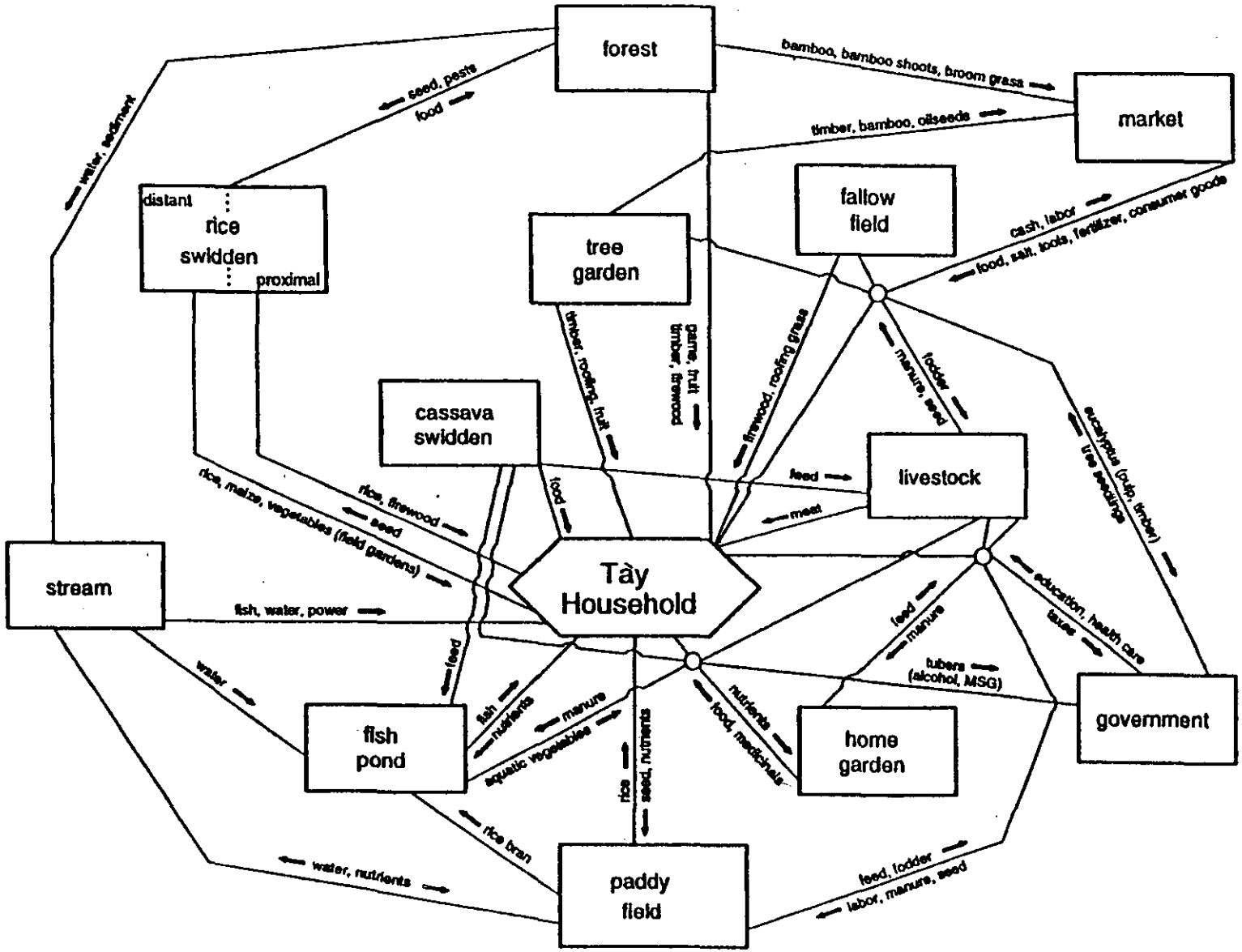


Fig. 1 : Nutrient flows in composite Swidden system (Da River watershed, Vietnam).

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