ESTABLISHMENT OF ECOLOGICAL MODELS FOR REHABILITATION OF DEGRADED BARREN MIDLAND LAND IN NORTHERN VIETNAM

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Le Van Lanh. 1994. Establishment of ecological models for rehabilitation of degraded barren Midland land in northern Vietnam. Rapid population growth and clearance of vegetation have exacerbated the widespread problems of soil degradation in the Midland region of northern Vietnam. This paper identifies optimum strategies for land use and management to rehabilitate degraded land. Rehabilitation methods must be appropriate to the socio-economic and ecological conditions and needs of the land owners, and should in particular take account of water conservation and erosion control.

Key words: Vietnam - rehabilitation - degraded lands - agroforestry - *Tephrosia candida*

Le Van Lanh. 1994. Penubuhan model-model ekologi untuk pemulihan tanah tandus yang ternyahgred di bahagian tengah di Vietnam utara. Pertumbuhan penduduk yang pesat dan pemugaran tumbuh-tumbuhan telah memburukkan lagi masalah penyahgredan tanih yang meluas di bahagian tengah Vietnam utara. Kertas kerja ini mengenal pasti strategi-strategi yang optimum untuk kegunaan dan pengurusan tanih bagi memulihkan tanah ternyahgred. Kaedah-kaedah pemulihan mesti bersesuaian dengan keadaan sosio-ekonomi dan ekologi serta keperluan pemilik-pemilik tanah dan terutamanya, mengambil kira pemuliharaan dan pengawalan hakisan.

Introduction

The Midland region of northern Vietnam surrounds the northern plain of the Red River delta. It covers an area of approximately two million hectares, mainly in the provinces of Vinh Phu and Ha Bac. Past and present landuse practices have contributed to soil degradation. These practices include

- careless use of forest resources (deforestation, the clearing of forest for land reclamation, over exploitation of forests for timber, fuelwood, industrial raw materials)
- shifting cultivation
- monocultivation of annual crops on sloping land
- extensive farming
- growing perennial crops by inappropriate cultivation methods;
- overgrazing

Project objectives

The project aimed to identify optimum solutions for land use and management to rehabilitate degraded land in the northern Midlands. The objectives were as follows:

- To identify suitable landuse models, including agroforestry, in the Midlands
- To determine appropriate species of wood plants and annual cash crops suitable for the ecologically degraded Midland areas
- To identify suitable species of leguminous and green manure plants for land rehabilitation and conservation

Environmental conditions

Climate

The Midland region experiences a tropical monsoon climate. The rainy season between May to October accounts for 85% of mean annual precipitation. During the dry season from November to April evapotranspiration is higher than precipitation, and droughts are frequent.

The mean annual temperature is between 22 - 24 °C. In the cold season the temperature drops to 15 - 16 °C. The highest temperature amounts to 32-33 °C. Noteworthy is the total annual mean precipitation as high as 1500 - 2500 mm, concentrated from May to September. The rain normally occurs as heavy showers which have an intensity amounting to 3.7mm/minute during 10 minute periods.

Relief

The relief comprises hills and ancient alluvial terraces. The hills resemble upturned bowls with slopes of 8-22° and flat or rounded tops. The altitude is from 10 to 150 m above sea level. The altitude and slope increase towards the mountain region. Narrow valleys lie between the hills. The rock here may be sedimentary (sand stone, shale), or metamorphic (clay, slate, phyllite, mica slate, gneiss), and may include granite, rhyolite, and liparite.

The river terraces may be divided into three types: terrace I (10 to 20 m high), terrace II (20 to 40 m high), and terrace III (40 to 60 m high). Terrace I is weakly dissected. There are fine sediment materials (clay, silt and sand) in the surface layer. Fine and coarse gravel occurs at depths of 2-4 m. The slope varies between 3° and 8°. Terraces II and III are strongly dissected. The hills often have flat tops with side slopes of between 5° and 20°. Sediment materials here are more coarse, with rubble and gravel at the soil surface. Ferralitic processes and petrification are very advanced, with plinthite outcrops in some places.

Vegetation

The original vegetation of the Midland region was complex tropical rain forest. At present the degree of vegetative cover is very low (23%). The dominant vegetation is now savanna with bushes and herbs: *Rhodomyrtus tomentosa, Melastoma candidum, Dieranoptesis linearis, Hedyotis auricularia.* There are some secondary forest species present such as *Canarium album, Litsea cubeba, Liquidamba formosana, Manglietia glauca, Styrax tonkinensis, Cinanmomum album* and *Ornosia tonkinensis.*

Some plantations have been established: *Eucalyptus* sp., *Pinus* sp., *Manglietia glauca, Styrax tonkinensis, Vercinia montana, Acacia mangium, Melia azedarach, Camellia* sp., *Rhus sucsedaceae*, bamboo and fruit species such as jackfruit (*Artocarpus nobilis*), persimmon, lychee and longan. Crops such as cassava, peanut, soybean, dry rice and tea are cultivated.

Soils

Soil classification

Most of the hill soils in the northern midland are yellow and red soils which can be classified into Oxisols (according to the U.S. taxonomy system) or Ferrasols (according to the UNESCO-FAO classification). The following are the main types of soils present:

- yellow or red soil on slate clay rock and metamorphic rocks (clay slate, mica slate phyllite, gneiss)
- yellow or red soil changed by the cultivation of water rice
- pale yellow soil on sandstone
- yellow and brown soil on ancient alluvial deposits
- yellow or red soil on magmatic rocks (granite, diorite, rhyolite), covering a small area at a higher altitude

The soil in the valley is alluvial and colluvial soils or Fluvisols according to the FAO classification.

Soil fertility

Due to the high temperatures and humidity, the weathering process is strongly accelerated and the weathering crust is about a dozen metres deep. Basic wash-out leads to increasing soil acidity. Clay formation in the acidic environment results in kaolinite clays with low absorption capacity. The iron compounds are dissolved, releasing iron which accumulates as concretion and plinthite. The plinthite horizon has a thickness of 60 - 100 cm and is located at depths of 40 - 80 cm.

In the northern Midland, slate clay and metamorphic rocks (phyllite, gneiss, mica slate) are common. The weathering crust on these rocks is rich in aluminium and iron. Due to weathering, it is poor in alkaline and alkaline-earth metals (pH_{KCL} from 4.0 to 5.5). In the surface layer, humus content is 1 - 2%, nitrogen 0.05 - 1%, total phosphorous ranges between 0.03 - 0.06%, and total calcium from 0.15 to 0.5%. The soil formed on rock (such as sand stone) is deficient in iron.

The soil in the valley is frequently flooded and receives sediments from the hills. The soil is very acid. It is possible that iron toxicity is the major constraint to rice yields.

Accelerated soil erosion

In the Midland water erosion may be intensive, particularly on the steep bare slopes. The lost soil contains many nutrients. Annually, 50-170 kg nitrogen, 7-35 kg K_2O, and 15-30 kg of organic matter are washed away from one hectare.

Shifting cultivation has been the traditional practice of the indigenous "minority" people. This is the main cause of the present degraded land in the midland region. As a result of the burning of dry residues and humus, the soil surface layer loses its biological activity. A decrease in humus content leads to the deterioration of the soil structure and increased susceptibility to erosion.

Structural degradation

Structural degradation is caused by

- loss of humus and clay minerals through shifting cultivation and water erosion
- compaction of the soil by heavy machines and tillage implements
- intensive trampling due to overgrazing

In the northern Midlands the first and the third causes are widespread.

Formation of concretion and plinthite

The conditions of formation of concretion and plinthite are as follows:

- strong ferralitic processes releasing aluminium and iron oxides
- alternation between dry and humid conditions
- change in pH value
- the moving of ground water with high iron content
- relief (altitude and grade of slope)

In the Midlands, the formation of concretion and plinthite from aluminium and iron oxides is a very serious problem, especially in soil formed on the ancient alluvial deposits and at the foot of hills where the ground water table is very high. The plinthite horizon is 80-100 cm thick and exposed on the surface. The thickness of the soil layer above the plinthite zone is of decisive importance for plant growth and workability of the soil. Exposure of the plinthite zone leads to decreased permeability and increased soil erosion. In some places the soil horizons above the plinthite layer have disappeared, resulting in severely restricted land capability and low yield and productivity of cultivated crops.

Social factors related to the project

Human population density

In 1945 the population of Vietnam was about 25 million, and the population density in the Midlands was only 25 - 50 persons km^{-2}. By 1989 the population had increased to nearly 65 million, and the population density in the Midlands is now about 500 - 600 persons/km^2. High population density and population growth are the underlying cause of land degradation. National family planning programmes aim to slow down population growth to a rate of 1.7% by the year 2000. The present rate is around 2.1- 2.2%.

Original land use

The original land use pattern in the Midlands was the clearing and burning of forest to obtain lands for cultivation of dry rice, corn, cassava and tea.

Rice is the main food crop of Vietnam. In the Midlands, paddy fields are located only in the valleys, and are frequently destroyed by floods and siltation resulting from hill erosion. Hill rice productivity is very low and decreases quickly after the first harvest. In the first year the yield of dry rice is about 1000 - 1200 kg ha^{-1}, in the second year 500 - 00 kg ha^{-1}, in the third year 300 kg ha^{-1}, and in the fourth year there is almost no harvest.

Cassava is the second food crop in the Midlands. Soil conservation is seldom practised in cassava cultivation, so the soils under cassava monoculture on steep slopes are susceptible to erosion. On 19 April 1982, 170 mm of heavy rain washed away 200 t of soil from one hectare of newly grown cassava field. Due to low soil fertility, cassava production is quite low, about 3-10 t ha^{-1} y^{-1}.

Tea is an important cash crop. Tea plantations which are neglected or not mixed with other crops develop slowly and become covered by grasses. Soil is exposed to the sun and hence is seriously eroded.

Palm, an indigenous tree in the Midlands, was planted some decades ago on some of the hillslopes. Palm forests are useful for soil conservation. Unfortunately, palm is now of little economic importance. Palm forests are therefore being replaced by tea plantation or by bamboos for raw material for paper production.

Land ownership

During the colonial period, most land was privately owned, although some villages retained communal land which was periodically redistributed to their citizens. Many peasants were landless labourers or worked as sharecroppers or tenant farmers on fields belonging to landlords. After the land reform of 1955-1956, estate land was expropriated by the state and redistributed to small farmers.

In 1960, two types of land management were established in the north. Most land was put under the management of cooperatives and, except for homegardens, was collectively worked by production brigades. State enterprises for large-scale production of cash crops were also established. Local farmers paid less attention to cooperative lands while the managers of the cooperatives lacked the knowledge and experience to manage such large-scale production; for a long time productivity was constrained.

Since 1989, the paddy fields, forest lands, and hill land with crops have been reallocated to households for management, with the promise of long-term land tenure (from 25 to 50 years). Each family has received a land tenure certificate. The villagers are thereby assured that they will benefit from the forests and the soil, and they have the right to leave these resources to their offsprings. This policy has encouraged the farmers to use as much fertiliser as possible, and to apply advanced agricultural techniques to promote production and to increase crop yields.

Legal constraints

With the new policies of land tenure mentioned above many farmers have used their lands rationally and obtained high productivity. However, some of them have not paid attention to restoration of degraded land; they grow cassava monocultures on steep slopes and eucalypts on very dry soil. These make the soil more degraded.

Since 1961,and especially in the late 1960s and early 1970s, the government of Vietnam has resettled hundreds of thousands of Kinh people from the lowlands of the Red River Delta to the Midlands in order to develop a "new economical zone" and in an attempt to relieve population pressure in the delta. Misapplication of lowland and delta agricultural techniques to the highlands have exacerbated forest destruction and land degradation in the Midlands.

Economic constraints

Most of the farmers have low incomes, and adequate credit is not available for them to develop agricultural production and to rehabilitate degraded soils. The new policy on land tenure is an incentive for improved agricultural practices. In some localities, tax exemptions encourage farmers to rehabilitate and conserve degraded land.

Restoration methods

Land degradation is common, resulting in an increase in bare hill areas, and decreasing crop yields and productivity. Incorrect land uses in agriculture and forestry have exacerbated this situation.

Land use and management

Intercropping annual crops with leguminous and green manure plants

The following patterns of intercropping are common in the northern Midland:

- Cassava and peanut
- Cassava and oregon pea
- Cassava and *Tephrosia candida*
- Maize and soybean
- Pineapple and *Tephrosia candida*

Intercropping leads to very high yields: cassava: 12 - 18 t ha^{-1} (fresh tuber) in fertile soil and 5 - 10 t ha^{-1} in degraded soil; maize: 1800 kg ha^{-1} (grain); peanuts: 500 - 800 kg ha^{-1} (dry nut); soybean: 1000 kg ha^{-1} (seed). Intercropping provides large inputs of fresh green matter which improves soil fertility : peanut: 19 t ha^{-1}; legumes: 7500 - 12 500 kg ha^{-1}; *Tephrosia candida*: 12 - 18 t ha^{-1}. Soil structure improves, water holding capacity and permeability increase and soil losses caused by water erosion decrease. Effects of legumes on soil loss and cassava production are shown in Figure 1.

Manure is allocated first to the rice field and homegarden, with any available surplus added to upland fields. Cassava fields receive 5.4 to 13.5 t ha^{-1} crop. Chemical fertiliser are used regularly but in relatively small amounts.

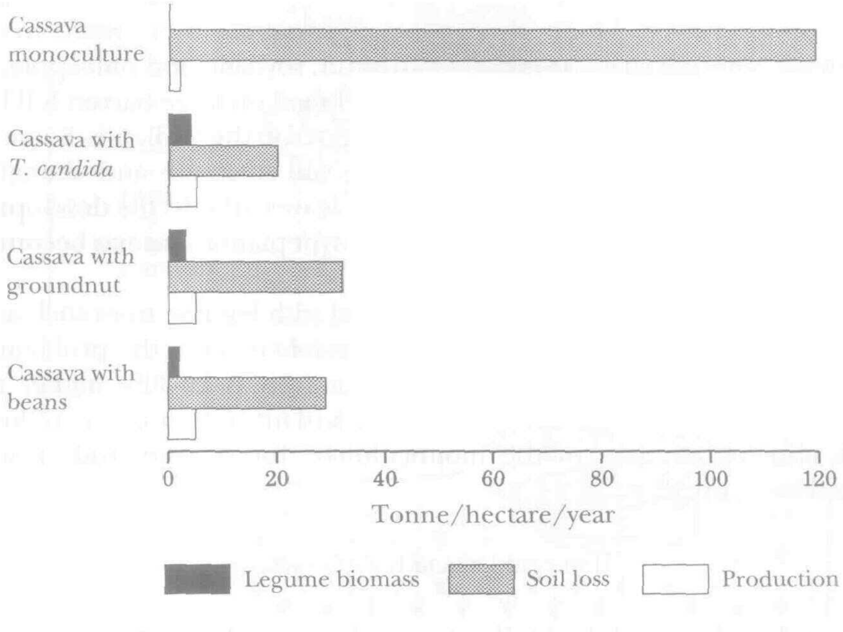

Figure 1. Effects of legumes on soil loss and cassava production

Tea plantation

Tea is an important permanent cash crop. It is planted along the contour in rows 40 cm wide on the soil surface, 40 cm deep and 30 cm wide under the soil. Before planting tea, *Tephrosia candida* is planted on the ridges and on the hill roads to provide shade. This increases soil cover and prevents erosion, retains soil moisture, and fixes nitrogen. The stems and leaves are left on the hill to enrich the soil. Young tea plants are covered by rice straw and dry grasses to maintain soil moisture. Urea is applied to the tea field at rates ranging from 50 to 135 kg ha^{-1}, and phosphorus fertiliser is applied at rates of 50 to 270 kg ha^{-1}.

Some scattered wood trees (e.g. *Cassia siamea, Vernicia montana*) are interplanted in tea plantations to provide shade for tea as well as for the farmers tending their fields. The suitable density is 150-200 trees per hectare. Such tea plantations annually yield about 6-8 t ha^{-1} of wet tea and the yields probably last 40-50 years.

This basic design of a tea plantation costs US$500-800 per hectare to implement.

Afforestation

Afforestation using a mixture of multipurpose species (providing fruit, fodder, firewood, as well as commercial timber) is one possible strategy. Incorporation of nitrogen-fixing species into such mixtures can also help to restore soil quality.

A lot of native trees have been used for reforestation. These include *Manglietia glauca, Styrax tonkinensis, Cinanmomum album, Melia azedarach*, bamboo, jackfuit, persimmon and lychee. In the process of afforestation, these wood trees were intercropped with hill rice, cassava, corn, peanut, soybean and pineapple.

In the 1980s eucalypt plantations were developed on large barren hill lands in order to provide raw materials for paper mills located in the Midlands. Some species of eucalypt have been blamed for degrading soil structure and changing soil fertility. It is believed that cinoel in the eucalypt leaves inhibits the development of flora and microorganisms. The soil under eucalypt plantations has become more compact and dry.

In the late 1980s eucalypts were interplanted with legume trees such as *Acacia mangium, Acacia auriculiformis* and *Tephrosia candida* to solve the problem of soil degradation. In the mixed forest, the soil humidity is 20-30% higher than in monocultured eucalypt forests, and the humus and nitrogen content in the mixed forest is also higher than in the monocultured forest. The study results are illustrated in Figure 2.

Homegarden and RVAC system

The rural landscape of the Midlands is fairly complex and the pattern of land-use reflects this. The landscape is composed of three major elements: moderately flat valleys between the hills; house plot and associated homegardens; and sloping uplands. Each of these elements plays a distinctive role in the overall agroecosystem and is associated with typical activities. This pattern has been described as the RVAC system. (R=rung=forest, v=vuon=garden, a=ao=fish pond, c=chuong=animal pen). Figure 3 is a diagram of the RVAC system in the Midlands.

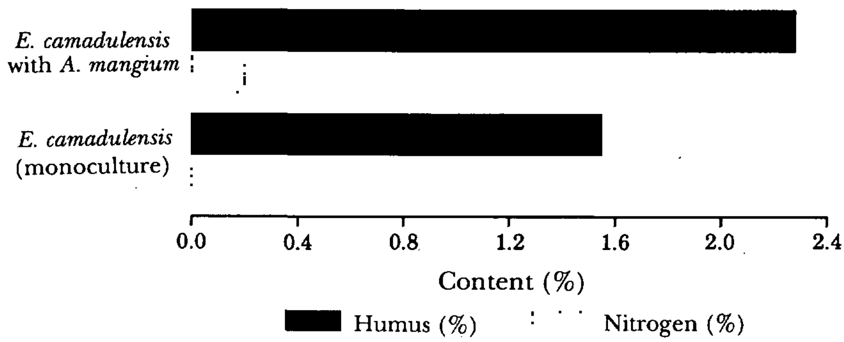

Figure 2. Humus and nitrogen content in the surface layer of the soil under monoculture and mixed forest

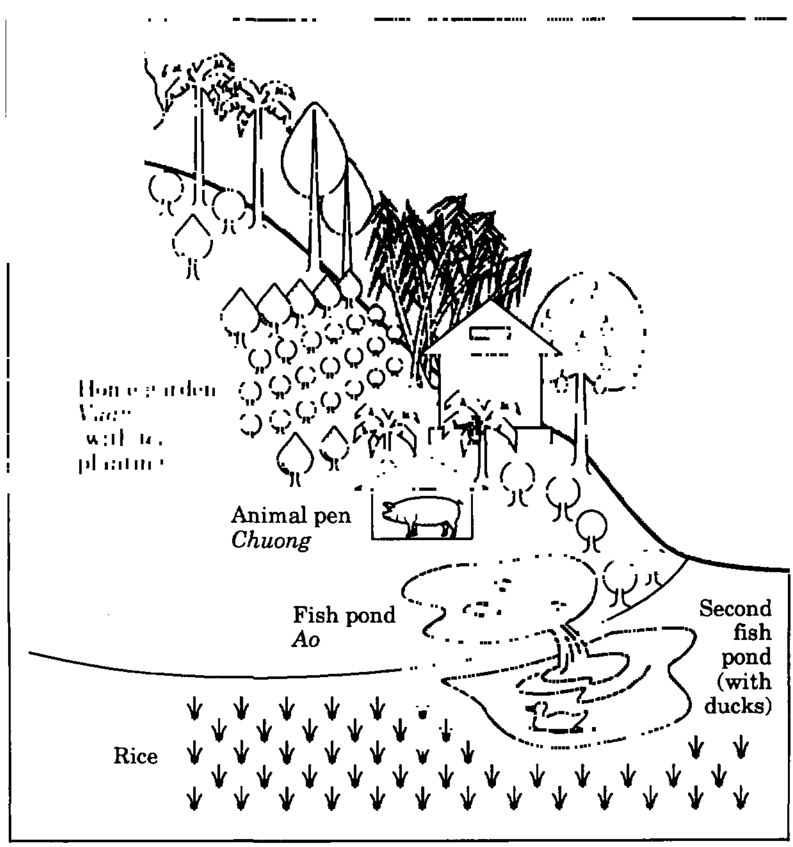

Figure 3. Diagram of a model (RVAC)

Valley-paddy fields and fishponds

In the valleys, the principle land-use subsystems are paddy fields, water resources (reservoirs, ponds and streams) and roads.

The paddy fields are on moderately flat, terraced and bunded lowland. In the Midlands, many households are unable to produce sufficient rice for home consumption and must supplement their diet with cassava. Liming was the standard management practice that farmers used to control soil acidity. Interception of the interflow and sediment is the most important practice to alleviate iron toxicity in rice fields.

Reservoirs, ponds and streams are predominantly found in the valleys. These water resources are used for irrigation, aquaculture, care of livestock and washing. The water resources also play a role in sanitation (carrying household waste away from the hamlet) and may improve microclimate. Fish raising in ponds and reservoirs provides animal protein to the household; ponds may receive inputs of household and animal wastes.

House plots, homegardens and animal pens

The house plots are most often located above the paddy fields, often on the lower part of a hillslope. The homegarden is also located there, with a diverse community of vegetables, fruit and wood trees and medicinal and decorative plants. The house plot is also the centre of animal husbandry. Animal pens are often between the house and fishpond. The animal manure is also collected for the household compost pile and used both in the homegarden and paddy fields. Cattle and pig manure is used to feed fish in fishponds if the topography and water conditions permit. Fish ponds and wells may be excavated at the lower part of the house plot. Bamboo, rattan and some wood trees are planted on the hill foot as a fence which prevents landslides and siltation of valley water resources.

Hillslopes

Three categories of slope may be distinguished: lower slopes, upper slopes and hill tops.

Lower slopes of less than 35° are devoted to tea plantations. Areas of mild slopes adjacent to house plots also tend to be planted with either tea or cassava. Cassava is produced as a supplement staple, for animal feed, for sale and for alcohol production. Tea is grown both for home consumption and for sale. Tea is intercropped with sparse wood trees for shade and to maintain soil moisture (e.g *Cassia siamea* and *Vercinia montana*); *Tephrosia candida* is being adopted for its nitrogen-fixing capabilities. Livestock are intensively grazed in tea fields.

The upper slopes exceeding 35° should be reforestation areas for fuelwood and commercial production. Indigenous fast-growing tree species such as *Styrax tonkinensis* and *Manglietia glauca* have been planted. Exotic species such as *Eucalyptus camaldulensis* have been mixed with *Acacia mangium* and *Acacia auriculiformis*. In the first years, perennial trees are mixed with *Tephrosia candida* to prevent soil erosion and to maintain soil moisture.

Hill tops should be used for agroforestry. Collection of firewood and construction wood and some grazing take place here.

Water conservation and erosion control

Water conservation, in the broad sense, is the most important soil management practice. The objective of water conservation is to increase the water penetration and holding capacity of the soil, i.e. to decrease surface runoff and soil erosion and at the same time to supply adequate water for crops during the period of drought. The following methods aim to achieve these objectives:

Water conservation practices. These are practices that hold water on the surface or slow down its movement to allow infiltration, and include terracing, contour farming and strip cropping.

Construction of reservoirs. Reservoirs play a very important role in flood control in the lowland region. The water in reservoirs is used for irrigation in the dry season. Reservoirs alter the adjacent microclimate considerably: the air moisture increases and the air temperature decreases. The higher ground water level promotes growth of vegetation.

Maintenance of adequate cover on the soil surface. Some practices used include: mulching the soil surface with dry grasses, litter and leguminous plants such as *Tephrosia candida* and *Styloxanthes gumilis*; using multiple cropping systems such as intercropping, rotation, sequential cropping; and preservation of natural secondary vegetation in fallow areas.

In the Midlands, *Tephrosia candida* has significant effects such as

- decrease in evaporation and soil temperature, increase in soil moisture
- decrease in soil loss
- supply of organic matter and nutrient element for soil
- improvement of soil structure

Characteristics of *Tephrosia candida*

T.candida is a nitrogen fixing tree or shrub occurring from the northwestern Himalaya to Tenasserim. Apart from characteristics common to other leguminous trees, including nitrogen fixing capacity and prolific seed production, the large leaf size is favourable for models of agroforestry. It grows rapidly even in acid and very dry soil where *Leucaena glauca*, a famous tree in Southeast Asia, cannot grow. *T. candida* produces biomass of about 12-18 t $ha^{-1}\ y^{-1}$ when mixed with cassava, 20-40 t $ha^{-1}\ y^{-1}$ ear in monoculture, and sometimes more. The biomass of *T. candida* makes excellent green manure because of its high nutrient content. Nutrient content in *T. candida* is shown in Figure 4.

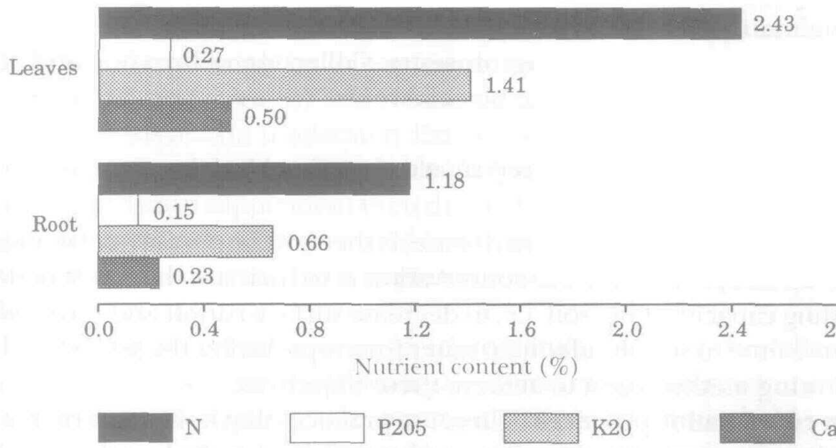

Figure 4. Nutrient content of *T. candida*

T. candida is very useful for rehabilitation of degraded soil. It can improve soil fertility over a 2-3 year period. The research results are illustrated in Figure 5.

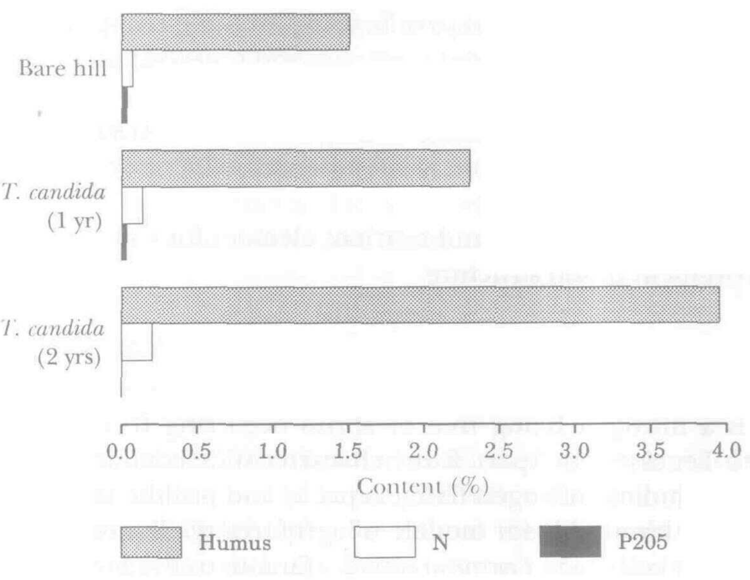

Figure 5. Effect of *T. candida* on soil fertility

When *T.candida* is planted with food crops on bare hills where other species cannot grow, the soil nutrient content increases 30-35% and crop yields increase. For example, yields of cassava increase about 25%.

Some species of eucalypt have been blamed for desiccating the soil. It is believed that cinoel in the leaves may inhibit the development of microorganisms and fauna. However, to meet the demand for paper raw materials and to aid soil conservation, a *Eucalyptus camaldulensis* - *T.candida* model was set up in the Midlands. *E. camaldulensis* grows about 100-120 m ha^{-1} in 10 years and soil fertility changes considerably.

Conclusion and recommendations

Rehabilitation of degraded land should be integrated into land use management. Rehabilitation methods must be appropriate to the socio-economic and ecological conditions and the needs of land owners. Methods of land rehabilitation should be closely connected with water conservation and erosion control.

Priorities should be given to: preservation of catchment forests; encouragement of permanent settlement and abolishment of shifting cultivation; persuasion of the local people not to grow annual crops on steep slopes; construction of reservoirs and fishponds at the hill foot in order to regulate surface water, microclimate and to irrigate crops on hills.

Annual crops should be rotated and alternated with leguminous plants, particularly *Tephrosia candida.* An appropriate cropping system needs to be identified which will increase surface covering degree all year round.

During the first years, permanent and wood trees should be mixed with leguminous green manure plants.

Mixed forests should be introduced to all the regions of the Midlands. Further research is needed on the effects of mixed plantings of *Eucalyptus camaldulensis* and *Acacia mangium.*

Tea is an important cash crop and is very useful for soil protection and rehabilitation. Credit should be given to the farmers to help them develop tea production in the Midlands.

The RVAC system should be promoted in settlement areas.

Grazing must be restricted in sloping land because trampling by cattle makes the soil more compact and susceptible to soil erosion.

Projects on rehabilitation of seriously degraded soil with thick concretion and plinthite horizon should be a priority.

Long-term security of land tenure should be assured. Tax should be exempted for the owners of degraded land which is being rehabilitated.

Family planning must be enhanced to decrease the population growth and relieve the pressure on natural resources, especially on forests and land.

Transportation and communication need to be improved to facilitate exchange of information and agricultural and forestry products between the Midlands and the Lowland.

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