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Tree gardening and taungya on Java: Examples of agroforestry techniques in the humid tropics*

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Abstract: Agroforestry is a general concept for a land management system combining trees and agricultural crops. For application, various specific techniques can be chosen. Each of these techniques is adjusted to a specific set of environmental as well as socio-economic factors. Agroforestry cultivators or managers belonging to varying social strata and institutional groupings may practice different forms of agroforestry, even within the same general region. This is demonstrated on the basis of two contrasting types of agroforestry which are found on the Indonesian island of Java. Tree gardening or the cultivation of a wide variety of crops in a multiple-storeyed agroforestry system is an indigenous practice on private lands, while taungya or the intercropping of young tree plantations with staple crops is practiced on state forest lands. Both systems are described as to their management characteristics, past development as well as possibilities and constraints for further development. These two practices are then compared as to various attributes, like producer group, production purpose, area of cultivation, land ownership situation, structural organization of crop combinations, possibilities for improved cultivation techniques, and suitability for application in rural development for specific target groups.

Introduction

Agroforestry as any form of land use is primarily determined by the local physical circumstances and the ecological characteristics of the plant and animal species. However, within the boundaries of the possibilities and restrictions as offered by nature, the choice of the actual land-use system is determined by the cultural, political, psychological, economic and social circumstances of the societies. Palte [18] has mentioned 11 socio-economic factors which might influence the existence of indigenous agroforestry systems, its management methods and/or the success of its introduction, to wit: demographic situation, farm size and land tenure, local power structure, village cohesion, presence or absence of certain social institutions, household income, labour force and utilization, productivity, commercialization and marketing, availability of capital and credit, extension.

In a specific area, various forms of land use can be present, each adjusted to different sets of physical and socio-economic factors. This also holds true for agroforestry, as will be demonstrated in this paper on the basis of

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two contrasting types of agroforestry which are present on the Indonesian island of Java. These agroforestry systems will be analyzed as to the environmental and socio-economic situation, which determine its presence, and to the possibilities and constraints for more extensive use and further development.

Tree gardening

Tree garden types

The term 'tree gardening' is used here to denote multiple-storeyed agroforestry systems where a mixture of several fruit and other trees are cultivated, sometimes with inclusion of annual crops. Originally, three different types could be distinguished on Java [25–27].

a) The home garden (pekarangan): fenced-in gardens, surrounding individual houses, planted with fruit and other trees, vegetable herbs and annual crops. Historically they are associated with wet rice fields and more recently also with dry fields. They occur in regions with individual land ownership, where the culture has a strong matriarchal background. Typically these home gardens occur in Central Java and are inhabited by Javanese people.
b) The tree garden (kebun or talun): mixed tree plantations on communal lands surrounding villages with dense clusters of houses, sometimes also at some distance from the villages. These plots are not inhabited and they are historically associated with shifting cultivation. They occur in regions with communally owned land and a strong partriarchal background. Mostly they are to be found in West Java and are inhabited by Sundanese people. These tree gardens are much less tended than home gardens and often much wilder.
c) Clumps of fruit or other trees planted on former fields used for shifting cultivation. These plantings could denote a right of priority of these lands for the people who planted the trees in an area of otherwise communal landownership.

Over the ages, gradual changes have taken place in these systems. The most important change was the extension of the Javanese culture and subsequent spread of home gardens. Also, gradually communal lands were divided among individual landowners, who by building houses in such individual tree gardens, converted them to home gardens. However, the effect of various cultures (Javanese or Sundanese) is often still reflected in the structure of home gardens, e.g. in Sundanese home gardens often more vegetables and ornamentals are found [1].

In other tree gardens, annual crops were introduced and management became more intensive. Also shifting cultivation virtually disappeared and in

areas with clumps of planted trees on fallow lands a conversion to tree gardens took place. Therefore, at the moment, it seems better to distinguish the following types of tree gardening [11]:

a) Home gardens (pekarangan): a land-use form on private lands surrounding individual houses with a definite fence, in which several tree species are cultivated together with annual and perennial crops, often with inclusion of small livestock.
b) Mixed gardens (kebun campuran): a land-use form on private lands outside the village, which is dominated by planted perennial crops, mostly trees, under which annual crops are cultivated.
c) Forest gardens (talun, kebun): a land-use form on private lands outside the village in which planted and sometimes spontaneously grown trees and sometimes additional perennial crops occur.

Presently, home gardens have a wider distribution than mixed or forest gardens, the latter are mainly present in West Java and in mountainous areas. Generally, from home gardens to forest gardens the cultivation becomes more extensive and the appearance becomes more like a real forest. Because of the inclusion of annual crops in home and mixed gardens, soil tillage is used, but this does not take place in forest gardens where a natural herb and/or litter layer can develop. In some areas a gradual transformation from forests to tree gardens can be observed which is effected by the cutting of forest trees, selection and introduction of other tree crops, planting of annual crops and building of houses [16].

Characteristics of tree gardens

Tree gardening is an important land-use form on Java, e.g. home gardens occupy around 20% of arable land. Indeed, the area of home gardens has increased with the increase of population. The tree-garden systems have various functions for the local population. These have been described extensively for the home gardens (e.g. [8, 23, 24, 26]). Mixed gardens and forest gardens have been described less thoroughly (but see [6, 16]). However, many characteristics and functions of all tree-gardening systems are often similar, although their relative importance may change from one system to another. These common denominators are:

a) The tree gardens are characterized by a large variety of mostly multipurpose plants in various vegetation layers (and sometimes animals, e.g. chickens, etc), which provide for a good utilization of environmental factors like water, nutrients and sunlight. This variety ensures a varied production of different materials throughout the year.
b) Most of the systems are dominated by perennial rather than annual crops resulting in a relatively high ratio of nutrients stored in the vegetation

A

B

C

Figure 1. Three types of agriculture – tree crops combinations applied by local farmers on Java [25]. (A) Home gardens (pekarangan) surrounding individual houses in villages with irrigated rice field between villages, Central Java. (B) Tree gardens (talun or kebon) occurring outside villages, a typical pattern in West Java and mountainous regions. (C) Rows of trees in and along fields (tegal-pekarangan) in areas with restricting soil or rainfall conditions, like in East Java.

to those stored in the soil. This ensures an effective nutrient cycle and relatively small hazard for leaching and erosion. An effective nutrient status is further maintained by the uptake of minerals through deeply rooted perennials from deeper soil layers and effective catchment of mineral inputs by rain, by nitrogen fixation of leguminose species, and in the case of home gardens by the input of domestic and animal wastes originating from the household.

c) The tree gardens are only part-systems: mostly they form a part of a whole farm system, which also comprises annually cultivated fields. Normally, the latter are used to produce staple, high calorific food stuffs (rice, maize, cassava), while the tree gardens are used to produce supplementary products with high nutritious value (proteins, vitamins, minerals), medicinal plants and spices, firewood, and sometimes also forage crops and construction wood.

d) Normally, the tree gardens are used to produce a small, continuous flow of these supplementary products for subsistence and a possible small surplus for sale to local markets. In time of sudden necessities (unfavourable

Figure 2. A tree garden in West Java with tea and banana in the understorey, cloves in the second storey and *Albizia falcataria, Erythrina* spp. and some jackfruit and *Maesopsis eminii* in the upper canopy.

climatic conditions or social necessities like marriage) higher production and marketing levels may be attained.

e) Although the general cultivation practices are rather standardized, important regional and individual variations in tree gardens occur. These variations occur in response to various factors:

i. *Local environmental variation:*
- Climate: generally the variation in annual crops, if included, is not very large as they are cultivated only in favourable climatic seasons (rainy season). The variation in tree crops is much larger, as they have to be adapted to variable climatic conditions over much larger periods, which are location specific.
- Soil: with a decrease in soil condition the amount of suitable tree species decreases. Also, as soil conditions become a limiting factor for the cultivation of annual crops, the effect of light competition by trees becomes more pronounced. Thus, well-developed tree gardens occur mostly on volcanic soils, while on tertiary soils tree gardens are very open or non-existent. Here rows of trees are often found planted in or along the fields, a land-use system locally called tegal-pekarangan (crossing between dry field and home garden).

ii. *Adaption to socio-economic conditions* like availability of additional land for production of staple crops, marketing opportunities, availability of labour and additional income opportunities. Up to a certain level the cultivation of tree gardens can respond well to changes in such socio-economic conditions by means of intensification of cultivation, shifting the ratio of perennials/annuals and sometimes also domestic animals and a certain degree of specialization in crops. Generally, a decrease in the availability of land results in intensification of cultivation and the inclusion of more annual crops. Also, when alternative income opportunities are present, cultivation is extensified (and near urban areas more ornamentals are included). Where good marketing opportunities present themselves (near cities), specialization in fruit production may take place.

iii. *Individual preference and skills*: the overall cultivation techniques of tree gardens seem rather standardized by dependence on local environment and socio-economic condition, but important individual variation can still occur depending on the experimental basis of individual skill and personal preference for certain crops (cf. [14]).

Possibilities and constraints for development of tree garden systems

Although many characteristics of tree gardens make them efficient production systems with a remarkable ecological and social stability [28], this does not mean that no attention needs to be given to possibilities for their further development. Attention to such development opportunities is necessary because of the following reasons:

- Although the systems are well-adapted to the traditional rural situation, at the moment very fast changes are taking place in these areas, to which traditional experience is sometimes not adjusted. Certain species or cultivation techniques in tree gardens might be well adapted to former circumstances, but not very appropriate under the present situation. Also, newly selected superior species (varieties) or techniques might still be unknown to the local farmer.
- Although in many systems the seemingly haphazard structure is based on distinct ecological knowledge and experience (as demonstrated in regard to light requirements of plants in home gardens by Christanty and Priyono [7]) still quite large differences in the efficiency of garden utilization sometimes occur and many poorly managed gardens are open to improvement.
- In various areas the existence of tree garden systems is under pressure from 'developers' favouring a single component approach (e.g. promotion of single crops for marketing or one-sided attention to aesthetic or health aspects) by which the very nature of this integrated system is endangered or several essential functions lost. Alternative development methods should be introduced to counter this pressure [23].
- It might be possible to extend this land-use form to other areas as a means to introduce stable forms of land use in areas which are deteriorating at the moment. Several authors [9, 22, 25, 26] have drawn attention to the possibility of using such tree garden systems as a means to combat soil loss and restore soil fertility on eroding lands.

Cultivation of tree gardens might be improved by various technical measures such as better choice of species/varieties, breeding programmes, improved propagation techniques (grafting), better regulated planting distances, removal of unproductive trees, better water management (drainage in wet season, irrigation and water storage in dry season), better soil management (if annual crops are included, sloping lands need to be terraced and use of compost or fertilizer increased), improved pruning techniques, introduction of new plant protection measures, improved animal husbandry, etc. [5, 8, 26]. Such technical measures should be evaluated not only in their effect on single components of tree gardens, but in their effect on the total system. A system approach might indicate oportunities for additional development, e.g. Soemarwoto and Soemarwoto [23] demonstrated how adjustments of home gardens to the modern rural situation might include activities such as introduction of biogas digesters or stimulation of home industries.

The appropriateness of several improvement techniques has been demonstrated in several home garden projects (e.g. [5]). Much less attention has been given to development of mixed or forest gardens. However, various limiting factors to the development of tree gardening have come to the fore. For home gardens it has been noted that the share allotted to them, together

with the intensity of cultivation, increases as the total amount of crop land per head decreases, down to the point where the average amount of crop land per head is only 0.15 ha. Where the amount of land is even less, the share of home garden land decreases, although there is a tendency at first to increase the intensity of the garden culture [19]. If home gardens are the only land left to people, crop diversity is often diminished in favour of staple food crops like cassava.

Also, in areas with mixed or forest gardens, it can be seen that these only occur on privately owned lands if sufficient other land is available for the production of staple foodcrops or if an additional income from outside agriculture can be obtained. Although in interviews they admit mixed/forest gardens provide higher returns in the long term than annual crops, farmers prefer the latter in the case of sharecropping (no security over future yields) or if only minimal plots of lands are owned (need for regular supply of staple foodcrops).

Trials to utilize the idea of tree gardening as a means to combat erosion and rehabilitate the soil on dryland farming areas, have not met with as much success as was originally anticipated. In many areas planting of fruit- and fuelwood species has been undertaken on private agricultural fields in government re-greening programmes for soil conservation. Trees were planted scattered over the fields or in rows (400–800 per ha), mostly in combination with ridging, and annual crop cultivation was allowed to be continued. These land-use forms to combat erosion resembled most closely the mixed garden or the 'tegal-pekarangan' system. Although under these re-greening programmes farmers readily planted the trees supplied free-of-charge, for which they received a planting fee, maintenance was mostly neglected. In extreme cases seedlings were pulled up soon after planting to obtain additional planting space for foodcrops. More commonly, trees were cut when after 1–2 years they became light competitors for agricultural crops. Also, in some cases trees were not planted in the dryland fields, but in existing home gardens. Most success was still obtained in areas with very poor soils, where foodcrops are less productive and where in consequence income from (fuel)wood was more attractive [20].

The taungya system

Historical development

The taungya system, locally called tumpangsari, was introduced on Java around 1856 as an establishment technique for teak (*Tectona grandis*) plantations. This introduction was in response to a rising demand for land and underemployment of the increasing rural population. In the Forestry Regulations of 1856 the system was seen as a means to assist in the creation of new agricultural lands, but in the new Forestry Regulations of 1881 the system is recommended only as a means to improve tree growth.

For a long time taungya was seen purely as an effective means of reforestation, diminishing planting costs and favouring tree growth. Still in 1953 it was stated [13]: 'a prerequisite of taungya is forestry, (. . .) the own objectives of the forest corporation may not be hindered by increased food production'. Consequently, longer agricultural occupation periods, larger tree planting distances or shorter tree rotations were not considered relevant as a means to promote taungya. However, since the beginning of the seventies this view was gradually lost and important developments have taken place to stimulate the agricultural production potential of the taungya system, and to adjust the system to the needs for rural development rather than to the needs for forest establishment only.

Characteristics of taungya application on Java

The main use of taungya on Java is for reforestation of teak plantations. During the last five years about 40,000 ha per year of teak plantations were established, practically all by taungya. (Once a normal age-distribution of plantations is reached, the annual area of reforestation will be 16,000 ha). Normally teak is cultivated in 80-year rotations in areas with a pronounced dry season. Most plantations have been established in areas with rather poor tertiary soils, where taungya was applied on slopes up to 30%.

Under the taungya system, a contract is made between individual farmers and the Forest Service, in which the area to be planted, period of agricultural cultivation and allowed crops are specified as well as the contract sum to be paid by the Forest Service for tree planting and tending. Normally a ¼ ha plot is demarcated per family. After clearing, intercropping is allowed for a period of two years with crops such as dryland rice, maize, pepper, peanut and soybean and under certain conditions also with cassava, potato and other crops. These crops are interplanted between alternating rows of direct-seeded teak and *Leucaena leucocephala* (as permanent covercrop). On sloping areas light erosion control structures should be established in the form of trash or stone ridges, planting rows along the contour and possibly drainage ditches. The tending of the trees takes the form of selection of leaders if more than 1 seed per planting hole germinates (of the 3–5 seeds used), additional planting in case of insufficient germination and early mortality, regular cutting of *Leucanea* (two times per year) and weeding. This tree tending continues for 3 years after the end of the intercropping period [15]. Supervision over the work is carried out by a foreman of the Forest Service assisted by four volunteers selected from the contracting farmers; together they supervise an area of 10–12 ha [12].

The taungya system is more labour intensive than establishment techniques such as direct planting in cleared lines or planting holes, but the Forest Service has to pay a much smaller amount. Total labour need for row or hole planting is 86–116 manday/ha and for taungya 120 manday/ha, but for the latter the Forest Service only has to pay 62 manday/ha [15]. A

further advantage of the taungya system for the Forest Service is that tree growth is normally better than under other establishment techniques, due to the more careful tending of trees.

Present developments and constraints of taungya

For many decades the sketched taungya system has given satisfactory results, providing food and labour opportunities for the local population as well as benefits to the Forest Service. However, with increasing population pressure the system gradually became less effective. For example, an attempt was made to satisfy the need for land by allocating smaller plots to more peasants. But this practice resulted in overcropping of the smaller plots and neglect of the trees, while the supervision became less effective because more contractors had to be controlled. Also, uncontrolled cattle grazing often took place after the end of agricultural intercropping [12].

To adjust the system to present conditions, trials for intensification of the taungya have been undertaken. These intensification efforts were based on the following activities [15, 21]:

- use of high-yielding varieties of agricultural crops;
- better forms of land preparation and management;
- use of fertilizers;
- plant protection;
- correct timing of planting and fertilizing with respect to rainfall.

Since 1972 such an approach has provided good results and it is being gradually applied over increasing areas. With the use of selected superior crop varieties, fertilization in the range 90–100 kg urea and 60–150 kg TSP per ha together with the use of insecticides if necessary, yields of dryland rice improved from about 700 kg to 2000–3000 kg/ha.

Although higher inputs are necessary for which investments are needed, outputs increase so much, that this intensification is highly profitable to farmers. In one study, the intensification was proved to be more profitable than the original systems, if yields were higher than 1700 kg/ha [15]. In order to allow the farmers to apply such systems, the Forest Service not only provides extension services, but also credit to buy the commercial inputs. The distribution of these inputs is centralized by the Forest Service. The farmers have to repay only 70% of the credit, as it is assumed that 30% of the inputs have benefitted the tree crops. Indeed, it has been observed that as a result of the application of fertilizers, the early tree growth increases significantly.

Although this intensified taungya system in teak plantations has proved its feasibility in many regions, where it has improved agricultural production, absorbed more labour (229 mandays/ha) and was profitable to the taungya peasant, in other areas several constraints to its application have become

apparent. These constraints are due to local conditions (correct inputs not yet known for all geographic conditions, lack of local farming tradition using intensified cultivation practices) and organisational aspects (sometimes lack of sufficient seeds of high-yielding varieties, shortcomings in relation to credit scheme) [21]. However, it can be anticipated that these difficulties will be overcome with time.

A second important development is the present use of taungya for reforestation of non-teak species, such as *Pinus merkusii* or *Agathis lorantifolia* (syn. *A. dammara*). Although the taungya system has also proven to be technically feasible for these species, its practical application is often more difficult than in the teak forests:

- These non-teak species are normally planted on much more fertile (volcanic) soils than teak and in these areas the competition for land between agriculture and forestry is often greater than on the teak land, due to the possibility of growing more profitable crops on these fertile lands. Especially at higher altitudes a year-round production of high quality crops like tobacco, potato or vegetables can often be obtained and here competition for land is fierce.
- In these new areas people are mostly still unaccustomed to the taungya system and consequently the care of trees is often neglected or trees are even damaged.

In response to this situation the following measures have been taken:

- In some areas of West Java, where damage to trees to prolong the agricultural cultivation period was very serious, this reforestation practice has been abandoned.
- In other regions the area of taungya cultivation was extended in order to allow more people to participate. In the mountaineous regions, where pines are usually planted, this has resulted in ever steeper slopes (up to 50%) reforested in taungya. Since in this cultivation all vegetation is cleared and as normally only superficial anti-erosion measures are taken, this taungya on sloping areas has often resulted in serious erosion.
- Experiments have been started to extend the period of agricultural intercropping from 2 to 5 years, by increasing tree spacings from 1 x 3 m to 1 x 6 m. Furthermore, multiple-cropping schemes have been initiated in which a rotation between agricultural crops, leguminose fuelwood crops, fast-growing leguminose trees and pines is used [4, 10].
- Furthermore, the possibility of cultivating useful fodder or medicinal crops under older tree plantations is tested [10].

Theoretically, the taungya system is well-suited as a development activity

Figure 3. Application of taungya on volcanic soils: *Pinus merkusii* interplanted with beans and potatoes.

for landless people and the Forest Service tries to include these people specifically in taungya schemes. Besides these agricultural means for rural development, the Forest Service also tries to promote the welfare of the taungya farmers in other ways. These include the provision of water, health services, educational opportunities and sometimes also housing, as well as development of beekeeping, forest grazing in older stands and the cultivation of new tree crops amendable to labour intensive management techniques, which can form the basis for household or village industries (*Melaleuca leucadendron, Morus* spp. for sericulture) [2, 4]. As King [17] already noted, if taungya is to be used as an effective means for rural development, such activities are to be incorporated with development of cultivation practices.

However, in some cases inclusion of landless farmers in taungya schemes has been less successful. On the fertile, volcanic soils, investment cost for vegetable growing in tuangya is often several times higher than the credit provided by the Forest Service, which is based on investment costs for dryland rice or maize cultivation on much poorer soils. Also, sometimes land-less farmers participating in the scheme have transferred their cultivation right to other people if they were in need of cash funds, to become only a land labourer on his allotted fields [10]. Thus, further adjustments are necessary to include the poorest rural population segments in taungya schemes.

Comparison of tree gardening and tuangya

The above descriptions demonstrate how under various situations of land ownership, social organization and production quite different agroforestry techniques were developed within the same region. A comparison of various characteristics of both systems at three levels of organization is given in Table 1.

Tree gardening is an indigenous form of land use on private lands, which has proven to be stable and which up to a great extent is adaptable to a changing socio-economic and cultural situation. Various improvements can still be made in these systems in response to the fast-changing rural situation. In various projects appropriate techniques for further development have been demonstrated, but a large-scale programme for its development is still lacking. Only very limited extension is given to farmers about development opportunities, mostly of a single component approach, and no credit is available for improvements. Mostly, tree gardens are part-systems of a total farm system and below a certain threshold value of minimal landownership or income security, this form of land use is no longer appropriate. This characteristic limits the possibility to extend these systems as a means to halt erosion and rehabilitate the soil on private lands, because in such cases the proportion of land devoted to the cultivation of basic annual foodcrops and supplementary crops might become unbalanced.

The taungya system is a form of land use developed by the Forest Service on state forest lands. These characteristics enable the participation of landless farmers, while the presence of a central supervisory organisation provides for introduction of modern agricultural practices, extension and credit services and the incorporation of this land-use form with other means of rural development. The system is profitable to landless and poor farmers as they have the opportunity to grow essential staple foodcrops, receive a monetary contract sum and sometimes are eligible for additional social amenities. However, this system only provides for a temporary production of agricultural crops and consequently its human carrying capacity is much lower than that from tree-gardening. The extent to which this method can be used is limited by the area of artificial rejuvenation in the forest estate

Table 1. Comparison of attributes of tree-gardening and tuangya systems.

	Tree-gardening	Taungya
Field level		
Production purpose	Multiple production of dietary supplements, energy crops, medicinal crops, etc.	Mainly wood with additional food crops
Diversity of agricultural and tree crops	High	Low
Temporal combination of trees and crops	Permanent	Temporary
Size of rejuvenation unit	Small, gap-like	Large, field-size
Age–class distribution of trees	Multiple age	Single age
Soil protection characteristics	Erosion hazard during whole rotation depending on inclusion annual crops and slope, normally minimal–small	Erosion hazard mainly during agricultural cropping period depending on slope and soil conservation techniques, sometimes considerable
Possibility for introduction of new cultivation techniques	Being tried	Well-proven and applied
Enterprise level		
Input basic resources		
– land	private farmer	forest service
– labour	private farmer	contracted farmer
– finance	private farmer	forest service
– present technology & organization	private farmer	forest service (credits & social amenities)
Availability of extension and/or credits for farmer	Presently very limited	Available from forest service
Complementarity to other forms of land use within enterprise	Annual irrigated or dryland cultivation	Forest plantations

Table 1. Comparison of attributes of tree-gardening and taungya systems. (Contd.)

	Tree-gardening	Taungya
Benefits to enterprise	Multiple supplementary foodstuffs and other products for self-sufficiency & limited additional marketing	Originally cheap afforestation, presently forest protection from illegal cutting
Benefits to farmers	idem	Basic foodstuffs for self-sufficiency or marketing & monetary contract sum
Regional level		
Annual cultivated area	Over 1 million ha	Some 10,000 ha
Destination of products	Mainly local use within region	Food mainly local use, wood marketed outside region
Possibility to absorb increasing population pressure	High, up to threshold value	Limited
Suitability for inclusion of landless people	No	Yes
Possibility for extension to other areas	Restricted by socio-economic factors like need for staple foodcrops and security of land, possible application in forest estate untested	Moderate (within limits forest estate) depending on forest policy

and thus is dependent upon the policy of the Forest Service in regard to choice of tree species, rotation period, etc. The overall area where this technique can be applied is very minor compared to tree-gardening.

Both agroforestry systems are appropriate forms of land use under their own specific set of environmental and socio-economic conditions, but if the systems are to be introduced outside the area of original development, many technical and society constraints must be overcome. One interesting possibility which has hardly been investigated yet is the introduction of tree-gardening on state forest lands.

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