LAND DEGRADATION & DEVELOPMENT

Land Degrad. Develop. **13**: 307–329 (2002)

Published online 3 July 2002 in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/ldr.508

MIXED TREE-VEGETATIVE BARRIER DESIGNS: EXPERIENCES FROM PROJECT WORKS IN NORTHERN VIETNAM

A. FAHLÉN*

Department of Physical Geography and Quaternary Geology, Stockholm University, Stockholm, Sweden

Received 19 February 2002; Revised 19 March 2002; Accepted 26 April 2002

ABSTRACT

There has been an increased interest in the use of vegetative barriers in acid-infertile upland management systems in Southeast Asia. This paper analyses the experimental designs and policies in early-1990s of using vetiver grass barriers (*Vetiveria zizanioides* L.) in microwatersheds with short-rotation tree plantations in Vinh Phu Province, Vietnam. Four different mixed tree-vetiver models on degraded Ferric-Plinthic Acrisols are discussed. It is concluded that the institutional approach of demonstrating vetiver barriers as a model had a poor cost-wise performance, and that the model itself did not address the underlying issues of land degradation due to uncontrolled harvest of organic matter from the forest floors. The institutional approach was tainted with price distortions and 'disbursement-oriented' actions. Alternative and more flexible on-farm approaches, using *V. zizanioides* or the indigenous leguminous shrub *Tephrosia candida* (Roxb.) DC as vegetative barriers, were found to be more cost-effective and likely to have a higher rate of adoption among farmers. The institutional changes in land allocation policies (securing long-term usufruct users and transfer rights of agricultural and forest land) that took place in Vietnam in the early 1990s, in combination with a reorientation of programme policies to support needs of individuals and farmers' households, are hypothesized to have contributed more to the 'regreening' of the hills, than any single approaches of technical barrier designs by the Swedish-Vietnamese Forestry Co-operation Programme (FCP) in northern Vietnam. Copyright © 2002 John Wiley & Sons, Ltd.

KEY WORDS: land degradation; Vietnam; *Vetiveria zizanioides*; *Tephrosia candida*; microwatershed; soil and water conservation; vegetative barriers

INTRODUCTION

Perennial woody species and herbaceous plants have been used in indigenous barrier systems in the Asian region for a long time (MacDicken, 1990; National Research Council, 1993; Thang, 1995). During the last decades there has been a considerable interest concerning the merits of applying vegetative barriers to support sustained productivity in agroecosystems on sloping lands in Southeast Asia (Garrity and Ragland, 1993). The vegetative barrier approach is here defined as barriers built from living or dead organic matter more or less positioned along the contour. The soil and water conservation (SWC) efficacy of herbaceous grass–legume barriers on sloping land is due to changes in runoff and sediment transport hydraulics (vertical and lateral flow retarding and sediment-trapping capacity) and soil stabilization from the below-ground root biomass (Dalton *et al*., 1996). Further, herbaceous grass–legume barriers represent a permeable flow-through system where surface runoff is laterally spread and redistributed across the slope rather than concentrated in rills or channels (Smyle and Magrath, 1993). If above-ground herbaceous barrier material is also used as a mulch transfer system, improved soil fertility can be obtained (Bregman, 1993).

*Correspondence to: Dr A. Fahlén, Department of Physical Geography and Quaternary Geology, Stockholm University, S-106 91 Stockholm, Sweden. E-mail: anders@agronova.se

The SWC efficacy of woody species is determined by the spatial and temporal distribution and positioning in the landscape, canopy structure, root distribution, litterfall capacity and management practices rather than any benefits from the inclusion of trees *per se* (Bregman, 1993; Van Noordwijk *et al*., 1998). Woody species may yield specific benefits such as improved soil macropore formation and infiltration capacity following root decay (Van Noordwijk *et al*., 1991) and stabilization of the upper 2–3 m of the soil stratum (Bregman, 1993).

It is increasingly recognized that potential benefits observed by on-station research have not triggered any widespread adoption among Southeast Asian upland farmers (Garrity *et al*., 1998; Pandey and Lapar, 1998). Some key constraints found to counteract with the adoption of tree-based contour hedgerows include high maintenance and establishment requirements, limited value added to farm income, unanticipated soil fertility problems due to barrier-crop competition, too dense hedgerow barriers on steep sloping lands, poor species adaptation and lack of planting material and insecure property/user rights arrangement (Cramb and Nelson, 1998; Garrity *et al*., 1998).

This paper discusses the implementation and policies of mixed tree–vegetative barrier designs during the early-1990s within the Plantation and Soil Conservation Project (PSCP) in the Midlands of northern Vietnam.

The objective of this study is to investigate (1) technical efficiency (effectiveness to reduce runoff, soil loss, nutrient leaching and maintain organic matter recycling capacity), (2) rate of farm-level adoption (degree of spontaneous adoption and spreading to allocated forest/agriculture land) and (3) the cost-effectiveness of mixed tree-vegetative barrier designs as implemented in pilot areas by the PSCP operating within the Swedish-Vietnamese Forestry Co-operation Programme (FCP) in northern Vietnam during the early-1990s.

STUDY AREA

The assessment is based on on-field surveys of mixed tree–vegetative barrier experimental designs, implemented by the PSCP in Phu Ninh (Phong Chau District), Van Xuan (Than Son District), Than Van (Tam Dao District) and the farm-level soil SWC site (Phong Chau District), all in Vin Phu Province (VP), reorganized into Phu Tho and Vinh Phuc Provinces in 1996. The location of the study area is illustrated in Figures 1 and 2.

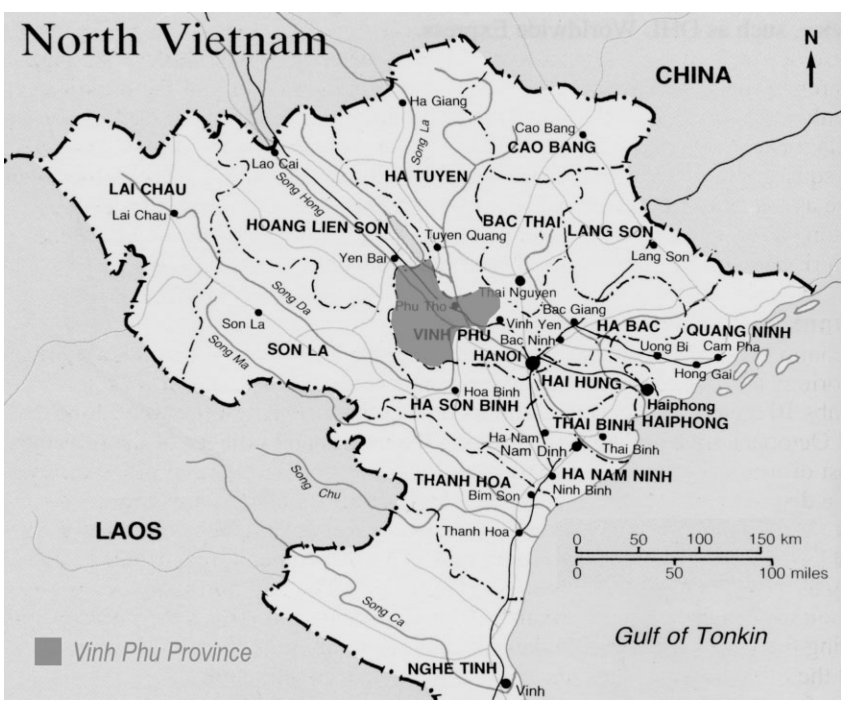

Figure 1. Map of northern Vietnam (pre-1996 provincial boundaries). *Source*: Modified from Népote and Guillaume (1992).

Figure 2. Map of Vinh Phu Province (pre-1996 situation) and location of the study area. *Source*: Modified from Tap Ban Do Viet Nam (1986).

Environmental Characteristics

The Midlands occupy an arc of undulating pre-Quaternary dissected terrain encircling the alluvial plains of the Red River Delta. According to Lanh (1994), parent material is dominated by sedimentary (sandstone, shale) or metamorphic (clay, slate, phyllite, mica, gneiss) formations, the latter may include acid magmatic rocks (granite, rhyolite and liparite). The hills have an average height of 150–200 m a.s.l., with convex slopes of 36–47 per cent (Cuc *et al.*, 1990). Along the major rivers the landscape evolution has resulted in three steps of landscape terraces. Weakly dissected terrace plateau (10–20 m a.s.l.) with depositions of alluvial and colluvial material in the surface layer (5–14 per cent slope) are found closest to the drainage lines. Alluvial deposits have developed along major stream lines (Young, 1985). In upslope areas terraces are strongly dissected with hills between 20–60 m a.s.l. (9–36 per cent slope) having gradually coarser texture in the soil surface layer. Plinthite and petroplinthite formation are common processes in these zones (Lanh, 1994).

According to the Vietnamese soil classification system soils in the study area are grouped into four major orders: (1) red-yellow soils derived from shale and metamorphic rocks; (2) yellow-red soils formed on acidic magma rocks; (3) light yellow soils formed on sandstone, and (4) yellow-brown soils formed on ancient alluvium

Table I. Major features of soil types in the Midlands, Vinh Phu Province

Vietnamese soil unit	Approx. FAO-Unesco soil unit	Soil constituents	Approx. soil profile depth*
Red-yellow soil formed on shale and metamorphic rocks	Ferric Acrisol	SiO_2:R_2O_3 ratio[†] < 2, redder than 7·5 YR, acid soil reaction ($pH_{KCl} = 4·0$–4·5), low available phosphorus content (high P fixating capacity);	0·6–1·2 m (thickest depth on soils derived from mica)
Red-yellow soils formed on acidic magma rocks (granite, liparite, porphyrite)	Rhodic[‡] Acrisol	SiO_2:R_2O_3 ratio < 2, redder than 7·5 YR, acid soil reaction, rel. high total potassium content;	approx. less than 1·0 m
Light yellow soils formed on sandstone	Acrisol/Gleysol/Lithosol/Luvisol	< 15% clay,[§] pH = 4·0–5·0,[§] low soil moisture storage capacity[§]	0·3–0·6 m deep[§]
Yellow-brown soils formed on ancient alluvium	Haplic Acrisol/Dystric Cambisol	SiO_2:R_2O_3 ratio < 2, pH = 4·0–4·5[§] approx. 20% clay[§]	deep soil profile[§]

*Soil features under natural vegetation cover; [†]Thuan, pers. comm.; [‡]suggested by Seghal (1989) but not included in the revised FAO-Unesco (1988) legend; [§]Silica:sesquioxide ratio.
Sources: Modified from Sehgal (1989), Khoa (1991), Siem and Phien (1994, 1995), Vien and Fahrney (1996).

(Cuc *et al*., 1990). Key features of the different major soil types and approximate equivalents in FAO-Unesco soil units are listed in Table I.

Simpson (1990) compiled soil analytical data from one–three-year-old forest plantations, in specific cases sampled from soils that later were used as PSCP experimental sites or from adjacent areas with similar soil–slope erosion conditions (Table II). The results by Simpson (1990) therefore provide indicative information about eventual soil-related constraints facing the establishment of tree-vegetative barriers by the PSCP. It is obvious that soil nitrogen, total soil phosphorus and exchangeable cation levels are generally very low (Table II). It is also noted that samples 1–4 (close to the PSCPs Tam Dao experiment) represent severely degraded Plinthic Acrisols derived from liparitic rock whereas samples 5 and 6 (close to PSCPs Phu Ninh experimental site at former *Eucalyptus* plantation) presumably corresponds to Ferric Acrisols derived from shale and metamorphic rocks and samples 7–9 (close to the PSCPs Van Xuan experiment) originate from moderately fertile Haplic Acrisols-Dystric Cambisols formed on ancient alluvium.

A reiteration and ANOVA analysis of the data presented by Simpson (1990) shows strong significant differences in means of CEC, soil organic matter content and total soil nitrogen content between sites that were visually classified having different levels of soil erosion (Table III).

It is concluded from Tables II and III, field surveys and provincial soil and land-use maps that the relative soil-related constraints following cumulative land degradation processes and inherent soil properties were as follows in the study area: Than Van > Phu Ninh (former *Pinus* plantation) > Van Xuan > farm-level SWC site (Phong Chau) and Phu Ninh (former *Eucalyptus* plantation).

The study area has a tropical monsoon climate where 85–90 per cent of total annual rainfall is received between April and October. Average annual rainfall during 1980–99 was 1710 mm (NISF, 2001). Temperature and rainfall data recorded at Phu Tho District are presented in Table IV.

The Midlands belong to the zone of closed seasonal tropical evergreen forest. Through human activity natural forest ecosystems have become increasingly disturbed and changed into secondary forests with bamboo (*Neohouzeana* sp., *Dendrocalamus* sp.), industrial tree plantations and rotational/permanent agroecosystems. Ferns (*Dicranopteris* sp.) are frequently found mixed with grass species (*Chrysopogon aiculatus*, *Eriachne* sp., *Eragrostis geneculata*, etc.) on severely degraded sloping lands that show the following features: A-horizon removal due to cumulative water erosion processes, plinthite and/or petroplinthite properties, increased bulk

Table II. Soil analytical data. Samples (0–10 cm) collected in Vinh Phu Province in May 1990 from 1–3 years old forest plantations (*Eucalyptus* sp., *Acacia mangium*) on 0–30 degree slopes

Sample	Location* (district)	Species†	Erosion Status‡	pH	N_{tot} (%)	P_{tot} (ppm)	K (meq %)	Ca (meq %)	Mg (meq %)	Na (meq %)	Mn (ppm)	CEC (meq %)	SOM§ (%)	Particle size analysis		
														Clay (%)	Silt (%)	Sand (%)
1	Vinh Yen	Ec	Sev	4·7	0·051	161	0·04	0·10	0·03	0·06	0·3	7·2	0·8	19	1	80
2	Vinh Yen	Ec	Sev	4·5	0·047	240	0·05	0·06	0·03	0·07	0·3	0·8	0·8			
3	Vinh Yen	A	Med	4·4	0·053	135	0·05	0·06	0·02	0·04	0·3	10·8	0·8	23	3	74
4	Vinh Yen	A	Sev	4·5	0·053	168	0·08	0·08	0·02	0·04	0·4	10	0·6			
5	Phong Chau	A	Med	4·2	0·112	213	0·08	0·17	0·10	0·05	3·1	16·4	1·4			
6	Phong Chau	A	Med	4·2	0·105	188	0·10	0·14	0·07	0·04	3·9	16·6	1·4	43	11	46
7	Yen Lap	Eu	Med	4·5	0·232	165	0·17	0·28	0·15	0·06	1·5	18·4	2·4	43	28	29
8	Yen Lap	Eu	Med	4·5	0·244	165	0·18	0·33	0·23	0·04	3·1	21·3	2·6			
9	Yen Lap	A	Med	4·3	0·217	138	0·09	0·07	0·07	0·07	0·8	20·0	2·1			
10	Yen Lap	Ec	Med	4·5	0·194	213	0·07	0·14	0·10	0·03	1·8	19·0	2·6			
11	Tham Than	Ec	Med	4·5	0·145	303	0·10	0·32	0·13	0·04	5·9	13·7	1·7	37	34	29
12	Tham Than	Ec	Med	4·7	0·127	259	0·12	0·38	0·11	0·06	9·2	13·9	1·2			
13	Tham Than	A	Lig	4·5	0·115	225	0·05	0·07	0·04	0·03	0·8	14·4	1·7	22	21	57
14	Tham Than	A	Lig	4·5	0·131	152	0·06	0·08	0·05	0·04	1·1	14·6	2·0			
15	Tham Than	Hy	Lig	4·6	0·114	207	0·08	0·19	0·05	0·04	1·4	13·4	1·5	28	8	64
16	Tham Than	Eu	Lig	4·6	0·210	431	0·09	0·14	0·07	0·03	1·9	22·7	3·6			

*Re-named to fit the pre-1996 district units in Vinh Phu Province; †A = *Acacaia mangium*, Ec = *Eucalyptus camaldulensis*, Eu = *E. urophylla*, Hy = Hybrid (*E.grandis* x *E. urophylla*); ‡Re-classified from Simpson (1990): Lig = light erosion, Med = medium erosion, Sev = severe to extreme erosion; §SOM = soil organic matter.
Source: Modified from Simpson (1990).

Table III. ANOVA analysis (Statgraphic Plus 5·0) of significant differences in means of soil-related dependent variables as a function of visual differences in rates of soil erosion at test sites[†]

Factor	Dependent variables						
Contrast[‡]	N_{tot} (%)	Soil organic matter (%)	CEC (meq %)	P_{tot} (meq %)	K (meq %)	Mg (meq %)	pH
Sev–Med	−0·115**	−1·179**	−10·563**	−55·396 n.s	−0·058*	−0·085**	0·123 n.s
Med–Lig	0·023 n.s	−0·288 n.s	0·288 n.s	−8·688 n.s	0·044*	0·059*	−0·106 n.s
Sev–Lig	−0·092*	−1·467**	−10·275**	−64·083 n.s	−0·013 n.s	−0·026 n.s	0·017 n.s

$^{**}p < 0{\cdot}01$; $^{*}p < 0{\cdot}05$; n.s = not significant; [†]23 soil samples from 1–3 year old forest plantations (0–30° slopes) in Vinh Phu Province and the southern parts of Ha Tuyen and Hoang Lien Son Provinces; [‡]Main contrasts: Severe to extreme erosion (Sev), medium erosion (Med), light erosion (Lig).
Source: Modified from Simpson (1990: Table 2).

Table IV. Climate data recorded at the meteorological station, Phu Tho District, between 1980 and 1996

Climate variable	Month (average monthly records)												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Temperature (°C)	16	17	19	24	27	29	29	28	27	24	21	18	23·3
Rainfall (mm)	33	43	64	106	218	242	299	265	217	141	63	19	1710
Evaporation (mm)	50	43	50	62	90	93	85	83	58	78	64	63	819

Source: NISF, 2001:Table 3.

density and soluble aluminium toxicity within the effective rooting depths. A severely degraded hill slope, Than Van, Tam Dao District, is illustrated in Figure 3.

A typical land-use transect includes wet rice on valley flat land and terraced sloping land, maize, sweet potatoes, industrial tree plantations (fast-growing, softwood tree species commercially used as pulpwood, fuelwood, building materials, etc.), food legumes on gentle slopes and cassava/tree plantations/natural fallows on medium-steep slopes. Multistorey home gardens are usually located in the foothills (Cuc *et al*., 1990).

Transport costs were predicted to escalate with increasing distance from the Vinh Phu Pulp and Paper Mill, Bai Bang, operational in 1982, therefore the Forestry Co-operation Programme (FCP) initially prioritized the establishment of industrial tree plantations within an 80 km radius (Young, 1985). Thus, the southern Midland landscape has been increasingly influenced by mixed and monoculture industrial tree plantations.

Figure 3. Plantation with *E. comaldulensis* on Plinthic Acrisol.

Population and Land Use

Since the defeat of the French Colonial Administration in 1954, the Vietnamese authorities enforced resettlement of hundred of thousands of migrants from the densely populated Red River Delta to the northern Midlands. Elder commune members state that old houses were built using local thick sawn logs that are no longer available as the area was heavily deforested within a couple of decades following in-migration of the Kinh ethnic group (Cuc *et al.*, 1990; Cuc, 1995). After the unification of the nation in 1975, new actions were taken to resettle lowland populations to the north, including the southern Midlands. It is estimated that somewhere between two and four million people were affected by these resettlements (Rambo, 1995).

Most of secondary forest areas in the Midlands have low species diversity due to continuous human-induced disturbances since the 1940s. Forest fragmentation processes typically include encroachment, agricultural frontier expansion (increased scale and intensity of agriculture, fuelwood collection and forest fires), commercial logging mainly governed by former State Forest Enterprises (SFEs) and illegal logging activities (De Koninck, 1999).

Population density in Vinh Phu was 464 persons km^{-2} according to the 1993 census (Cuc *et al.*, 1996). The per capita distribution of agricultural land at district level was: 0·11 ha (Phong Chau), 0·13 ha (Tam Dao) and 0·19 ha (Than Son) respectively (Vinh Phu Province, 1990).

The 1992 Land Law introduced a 50 years' land-use right for perennial species that was supposed to increase the farmers' interest in making long-term investments in forest-based land use. Fox and Donovan (1997) concluded that the new forest management policies in Vietnam were different compared to elsewhere in Southeast Asia as farmers were given widespread transfer rights over state-claimed forest land for long periods. Fox and Donovan reported from field visits in 1995 that forest regrowth on farmers' land in the Midlands was encouraging. However, field surveys done in selected districts in 1994 showed that many individuals had not gained access to forest land. Co-operative leaders, People's Committee representatives and the individual purchasers of forest land gave disparate information on the approved rates of taxation and the actual length of land-tenure rights (Rambo *et al.*, 1996). Donovan (1997) concluded from research in Than Hoa District that forest hill land controlled by village co-operatives and SFEs in the early 1990s was frequently encroached and degraded by villagers and employed workers as few households could qualify for the co-operatives' directive on minimum capital investments and labour requirements. The monitoring and enforcement capacity of the village co-operatives, SFEs and Forest Departments were also generally weak.

METHODS

The author was contracted by the Swedish supporting consultant (Interforest AB) to independently conduct assessment and analysis of the project's SWC activities (Fahlén, 1991, 1994). Field visits were undertaken in the study area in November and December 1990, February and March 1991 and July and August 1994. Findings are based on information achieved from: (1) field visits in collaboration with local extension staff to the PSCP sites in Than Son and Phu Tho Districts, the research site in Tham Dao District co-managed by the Forestry Research Centre (FRC), Phu Ninh and the International Board for Soil Research and Management and the farm-level SWC site in Phong Chau District; (2) discussions and interviews with local PSCP, Vinh Phu Service Union (VPSU) and Farm Level and Forestry Project (FLFP) staff; (3) discussions and interviews with FCP expatriate technical staff; (4) interviews with research staff at the FRC; (5) visits and interviews with key personnel at national/regional institutes in Hanoi, such as the National Institute for Soils and Fertilizers, Centre for Natural Resources Management and Environmental Studies, Forest Inventory and Planning Institute and Ministry of Forestry; and (6) dissemination of research and project documents.

Operational and fixed-cost estimates were obtained from PSCP staff. Information from local PSCP staff on annual tree growth rates, farm-gate prices, interest rates and inflation rates were cross-checked by the author with information achieved at national/regional institutes in Hanoi.

Population and land-use data were obtained from FCP documents, Phu Ninh and from enquiries at the Division of Statistics, Viet Tri (Vinh Phu Province, 1990). In addition, land-use maps from 1992 (1:100 000) were studied at the Forest Inventory and Planning Institute to assess tree cover distribution and soil maps (1:100 000) at the National Institute for Soils and Fertilizers (NISF) to assess soil distribution in the study area.

The author's experiences from similar upland environments in Southeast Asia during the 1989–2002 period are included in the recommendations whenever found relevant.

THE PLANTATION AND SOIL CONSERVATION PROJECT

Objectives

In 1986 the Plantation and Soil Conservation Project (PSCP) was established with financial support from Sweden to implement large-scale industrial plantations in northern Vietnam. The PSCP included four units during the 1986–91 period: forestry research, industrial plantations, social forestry and training. The implementation of the PSCP was directed by the Vinh Phu Service Union provincial state authority. The programme was expanded in 1991 and re-organized into the FCP. The objectives and organization of the FCP, including a general description of the PSCPs tree-vegetative barrier approaches, are illustrated in Figure 4.

The PSCP focused on industrial tree-crop management, watershed rehabilitation and high-value timber plantations in the five provinces of Vinh Phu (VP), Tuyen Quang, Ha Giang, Yen Bai and Lao Cai respectively. A training component was also added, including human resources development at state and co-operative forest management units (Ham, 1991).

In 1993, the PSCP initiated experimental vetiver barrier designs in combination with industrial tree plantations (*Eucalyptus* sp. and *Acacia* sp.) at selected sites in Vinh Phu. The objective was to develop erosion control techniques, preferably using vegetative barrier species adapted to degraded microwatersheds, to improve and sustain tree growth rates. Previous experiences with *Eucalyptus* sp. were discouraging, yielding low net economic returns on degraded soils in Vinh Phu (Young, 1985; Simpson, 1990). The director of PSCP stated that the project lacked previous experiences in SWC practices on forest hill lands (Ham, 1994; personal communication).

The Mid-Term Review (1994) proposed that the PSCP had fulfilled its main objectives in 1994 and therefore would terminate. Some 5000 ha of industrial plantations[1] as well as 500 ha of watershed rehabilitation and high-value timber stand improvements were implemented during the 1991–94 period (Mid-Term Review, 1994). A significant proportion of watershed rehabilitation and high value timber plantations were implemented by the Vinh Phu Service Union outside Vinh Phu (FRC, 1993; FRC, 1994a). The PSCP's watershed rehabilitation works in Vinh Phu started in 1992 with 8·5 ha of mixed woody species trials on degraded soils including *Eucalyptus* sp., *Acacia* sp. and *Tephrosia* sp (FRC, 1992) and a few hectare of combined vetiver grass plus stone check dam trials on severely degraded soils in Tam Dao District (FRC, 1993; FRC, 1994b). It is important to note that plantation and afforestation area targets described in the PSCP's annual work plans were far from being achieved as credits from the Viet Nam Agricultural Bank were not released for several years and the state credit policy did not allow for loans used in tree rotations longer than 20 years (Ham, 1991; Mid-Term Review, 1994). For example, in 1993 only 3170 ha of industrial softwood trees were planted as compared to a targeted 5000 ha (Mid-Term Review, 1994: 25).

FINDINGS AND RECOMMENDATIONS

Tree–Vetiver Barrier Design, Phu Ninh (Phong Chau District)

In 1993 the PSCP established a SWC experimental site just north of Phu Ninh, including two microwatersheds of 9 and 10 ha on Ferric-Plinthic Acrisols. The PSCP's objective was to rehabilitate degraded sloping land and to improve tree growth rates using a mixed *Eucalyptus–Acacia–V. zizanioides* L. barrier design. The area was formerly afforested with *Eucalyptus* sp., but the species growth rate was unacceptably poor due to degraded soil conditions according to PSCP staff (the soil surface showed ferric and plinthic properties). The PSCP viewed that it was feasible to redesign the area into a model site. In agreement with local land users to whom land was allocated

[1]The management responsibilities of industrial plantations were shifted to the province authorities in July, 1993, apart from six SFEs still administrated by the Vinh Phu Service Union and PSCP.

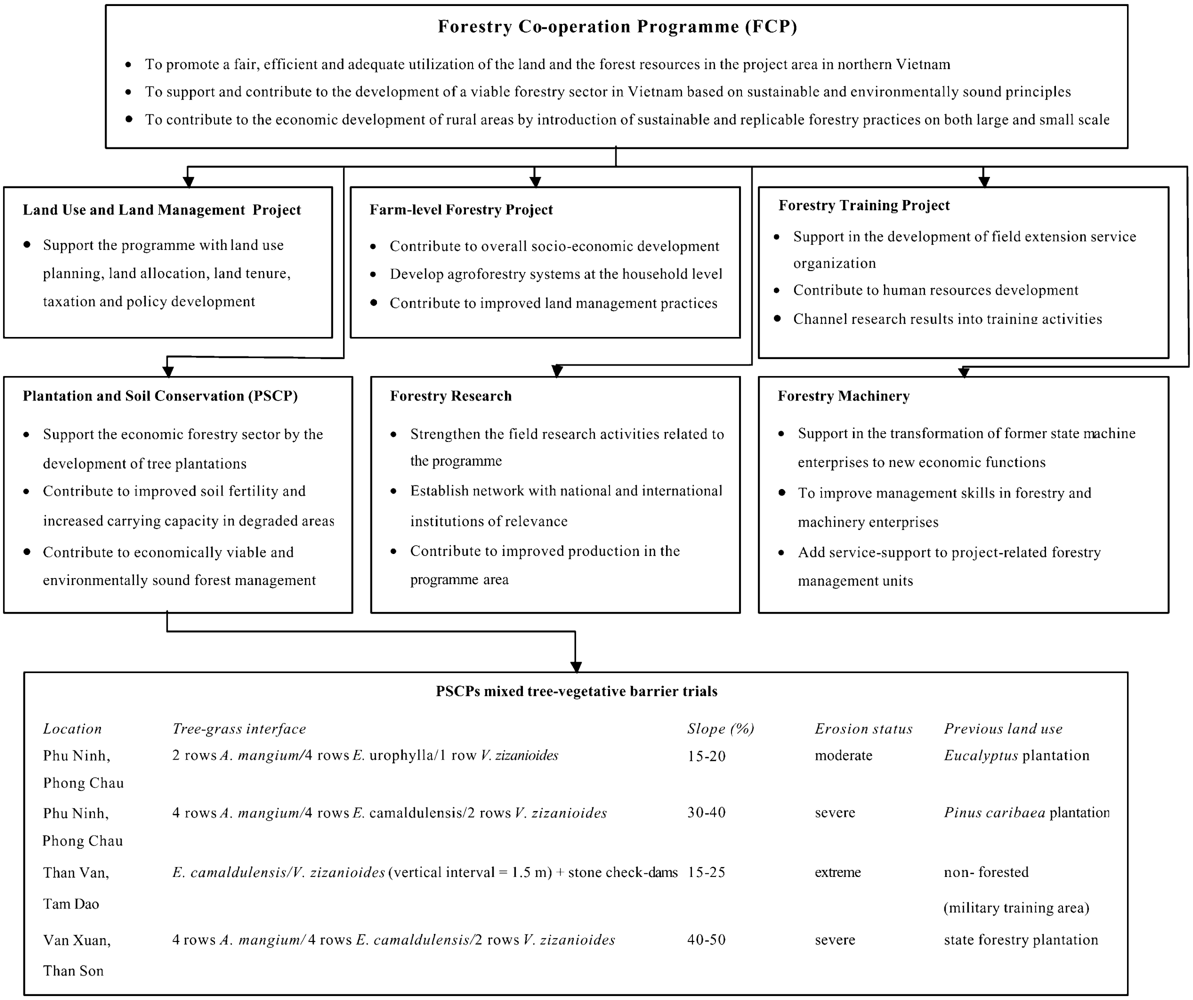

Figure 4. Objectives and organization of the FCP during the 1991–96 period (Interforest, 1991), including an overview of the PSCPs tree-vegetative barrier trials in Vinh Phu Province.

on 25 year lease, the PSCP designed an agroforestry system including two rows of *A. mangium* interplanted with four rows of *E. urophylla* and one contoured vetiver grass strip ($s = 5$–20 per cent). The ground-level distance between two adjacent grass strips was 10 m (Figure 5).

The PSCP and model farmers agreed to prohibit grazing during the first three years of establishment, in exchange for a 30 per cent share of tree harvest revenues. In nearby *Eucalyptus* sp. plantations outside the demonstration area ground cover was significantly less densely developed as litter collection and grazing were still practised. Records of labour inputs during establishment and maintenance were collected by the PSCP's staff, but no measuring of erosion rates, runoff or leaching was done.

The PSCP staff reasoned that (1) the inclusion of *A. mangium* would yield improved benefits compared to monoculture *Eucalyptus* sp. on degraded soils and (2) vetiver grass would further reduce rates of soil loss, runoff and nutrient leaching. Foliar analyses sampled by FRC showed higher concentrations of nitrogen and phosphorus in *A. mangium* than *E. camaldulensis* or *E. urophylla* whereas calcium, magnesium, manganese and aluminium levels were lower (Simpson, 1990). Soil samples from FRCs research plots in Vinh Phu showed that pH, organic matter content and total and available soil nitrogen (0–20 cm) were higher in *A. mangium* stands than in *E.*

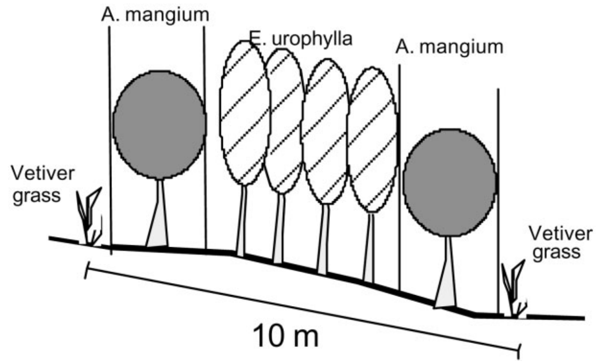

Figure 5. The PSCPs mixed tree-vetiver barrier model in Phong Chau District, Vinh Phu Province.

camaldulensis after four years. Mixed *A. mangium–E. camaldulensis* plantations in Vinh Phu showed higher pH, organic matter and available nitrogen contents (0–20 cm) in mixed systems than in corresponding monoculture systems (Cuc, 1996).

However, research by FRC in Lap Thac District indicates that mixed *A. mangium–E. camaldulensis* interfaces produced some 14 per cent and 18 per cent less above-ground biomass compared to monocultured tree plots after three years (Cuc, 1996). Both height and stem diameter were reduced in the mixed plots compared to the corresponding monocultured plots. This effect may be due to a less efficient spatial arrangement, density was 1700 trees ha^{-1} with one row of *E. camaldulensis* interfaced by two rows of *A. mangium* and thereby increased light–water–nutrient competition in the multi-storey mixed tree design. The mixed tree canopy was less dense after two years compared to monocultured *A. mangium* and had a distinct two-storey structure.

Mixed Tree–Vetiver Barrier Design, Phu Ninh (Phu Tho District)

At Phu Ninh, a former SFE plantation of *Pinus caribaea* on Ferric-Plinthic Acrisols was converted by PSCP into a mixed tree plantation (*E. camaldulensis* and *A. mangium*) in 1993 and allocated to individual forest land use. The experimental design included two contoured vetiver grass strips between every fourth row of each species (Figure 6). The hillside was steep ($s = 30$–40 per cent) and dissected into terraces that remained from the former

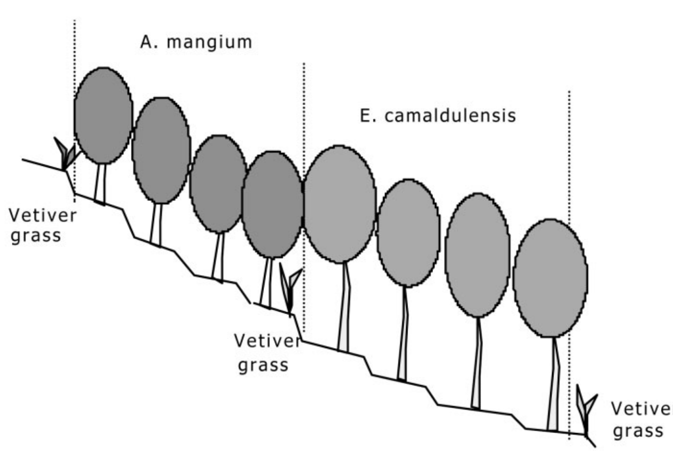

Figure 6. The PSCPs mixed tree–vetiver barrier design at Phu Ninh, Phu Tho District.

pine plantation. The vetiver grass did not perform well on the degraded soil.[2] Whether this could be altered by alternative species/cultivar selection or management techniques remained to be verified.

A network of large rills caused by concentrated water flow covered the soil surface and the under-storey vegetation was poorly developed. The terrace system was not designed to safely discharge excessive runoff volumes but rather intended to improve tree growth performance until canopy closure and to facilitate management operations. At larger depressions, moving water and sediments had bypassed the grass barriers. However, it was also visible that finer sediment material was trapped in front of the grass barriers.

Soil nutrient deficiencies, particularly phosphorus and boron, in the previous *P. caribaea* stand were probably severe (Simpson, 1990).

A combination of simple physical measures (stone check dams) in larger rills and depressions at fixed vertical distances, in combination with vegetative barriers, should yield improved erosion control on the steep slopes, as visually seen at the PSCP *Eucalyptus*–vetiver barrier design in Than Van. The PSCP respondents mentioned that former pine plantations managed by the SFEs were encroached and cut down by farmers.

Eucalyptus–Vetiver Barrier Design, Than Van Village (Tam Dao District)

In 1990–91 the PSCP afforested a severely degraded microwatershed area of 10 ha with *E. camaldulensis*. The hillslopes were previously used as a training area for heavy military vehicles. The entire A-horizon of the soil profile was eroded and due to hardpan formation[3] in the B/C layers the site was ripped by machine to 60 cm depth prior to tree plantation. The land rehabilitation scheme included strips of vetiver grass clumps planted in 1993 at a vertical interval of $\leq 1{\cdot}5$ m, reforestation with *E. camaldulensis* and small stone check dams in larger rills and gullies. Figure 3 showed a hillslope with *E. camaldulensis* and Figure 7 illustrates the PSCP's tree–vetiver barrier design with stone check dams. Animal manure was added at a rate of 2 kg per metre grass strip during establishment. After the first year, 200 g of compound NPK-fertilizer (2:1:1 ratio) was added per metre grass

Figure 7. The PSCP tree-vetiver barrier design, including stone check dams.

[2]It is doubtful whether *any* other species would perform well during the initial phase of rehabilitation of the acid and low-fertility soils of the area.

[3]Also known as *plinthite* in substitution for the old term 'laterite'. Plinthite may irreversibly harden into a hard crust, *petroplinthite*, when drying.

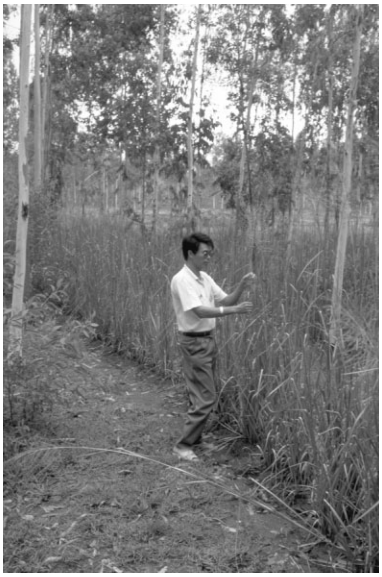

Figure 8. Vetiver barriers at the downhill section of a treated hillside.

Figure 9. Sediment and debris trapped in front of the vetiver barrier.

strip. Labour input during the establishment phase (i.e. planting of two rows of vetiver grass per contour line) was 20 workdays ha^{-1} (PSCP; personnal communication).

The vetiver barriers performed comparatively better downslope as a result of in-field erosion-sedimentation processes (Figures 8 and 9). The improved soil conditions at the tail section resulted in recovery of native ground cover (Figure 10).

Mixed Acacia–Eucalyptus–Vetiver Barrier Design, Van Xuan (Than Son District)

The PSCP implemented a land rehabilitation scheme of some 6 ha in 1993 in a microwatershed at the Van Xuan SFE. The mixed tree species arrangement was similar to the design used at Phong Chau. The sloping land was cross-fenced vertically and horizontally (double rows) with vetiver barriers replicated downslope at intermittent intervals of 10–15 m. The convexly profiled microwatershed was steep (40–50 per cent) with frequent rills and gullies in lower and steeper sections. Pedestals were found (50–100 mm) indicating significantly reduced soil depth

Figure 10. Early succession of regrowth of native grass species at the downhill section of treated land.

over time. There were no signs of hydraulic filtering or sedimentation processes in front of the vetiver barriers. During establishment, the PSCP staff said that weeds and pruned vetiver grass material were used to mulch tree seedlings. In the upper section of the microwatershed native creeping legumes and prostrate grasses had started to regenerate. The author observed a considerable within-row and between-row variation in tree growth rates, suggesting significant soil fertility changes at the field and microwatershed scales.

General Findings

It was viewed as important to identify human actions and institutional settings that specifically triggered land degradation in the study area. Forest floor regeneration was generally significantly better in the experimental areas (e.g. the *A. mangium* trial plots in Than Son District), where grazing and litterfall collection were regulated and monitored, rather than on adjacent village forest land.

Brown *et al*. (1995) concluded from studies of native pine reforestation in southern China that it is not sufficient to improve badly degraded soils by merely planting trees, if the forest floor is not managed properly. In this specific case total forest biomass was only 94 $t\,ha^{-1}$ after 50 years of pine forest cover, signalling losses of key ecosystem functions, particularly those concentrated at the atmospheric–terrestrial and plant–soil interfaces, by a continual removal of the forest floor. Local people were not allowed to cut trees but allowed to continue to harvest understorey plants and trim dead branches, thereby reducing the nutrient capture from atmospheric sources, the amount and rate of organic matter accumulation in the soil and soil nutrient holding capacity. Likewise, loss of forest floor also resulted in irreversible losses of nutrients from the ecosystem (Mo *et al.*, 1995).

Donovan (1997) found that forest land reallocation at village levels in Vinh Phu during the early-1990s was confronted with several problems. Specifically, co-operatives and Village People's Committees strived to maintain profitable forest land by non-uniform exclusion of resource-poor villagers. The co-operatives also faced problems of maintaining accountability and enforcement capacity in relation to individual households and hired forest labours. Illegal removal of forest products and forest floor biomass continued at significant scales (De Koninck, 1999).

The head of the PSCP imposed a guarantee that industrial tree plantation was positively linked to land rehabilitation. The author considered that the PSCP needed to review how to (1) increase biomass productivity and sustain tree plantations on sites with medium to good soil fertility and adapted to the new conditions of long-term user rights arrangement and market incentives (the 'plantation' component) and (2) identify soil-improving activities in combination with enforced and monitored forest floor management activities on degraded hillslopes (the 'soil conservation' component). By default, the mutual inclusion of the two components did not necessarily reflect the most successful approach.

A principal first step to improve soil fertility on degraded soils would focus on ground-cover maintenance rather than tree canopy cover. If user right arrangements allow for efficient forest floor management, research done in the study area verifies that suitable leguminous trees/shrubs will improve soil fertility on degraded sloping land (Simpson, 1990; Cuc, 1996). Significant improvements are thought likely to evolve slowly over time.

There were no visible signs that any of the PSCPs tree–vetiver barrier designs had attracted neighbouring villagers to implement such technologies on allocated forest hill lands. In fact, the PSCP staff found it difficult to interpret the purpose behind their own terminology 'SWC models', and had so far not developed any strategies to replicate findings from the demonstration sites to the farmers' land. It may be argued that the PSCP's demonstration sites had been operating for a too short period to be able to result in any significant impacts on adjacent farmers' land. However, it was observed that villages nearby had spontaneously initiated tree species diversification during the 1990–94 period. Species like *A. auriculiformis*, *Styrax tonkinensis* and *Manglietia glauca* were often interplanted in *Eucalyptus* forest stands purchased and reallocated from village co-operatives. Similar findings are reported from field research in Vinh Phu by Donovan (1997). Thus, the author concludes that individual households' management of relocated forest land was primarily attracted by increasing tree species diversity of commercial values as well as thinning and pruning operations[4] rather than erosion control techniques. Since land was now allocated to individual land users, farmers may have gained incentives to spontaneously redevelop supportive hydrological links between hill slopes and valley flat land at the microwatershed scale (e.g. woody-herbaceous filters across slopes).

The author noted that vetiver barriers or stone check dams were not systematically replicated downslope. Rather than adjust the horizontal interval between two adjacent barriers as a function of slope gradient, a fixed slope length was used. Terrace risers and vetiver barriers had sometimes collapsed due to concentrated overland flow (Phu Ninh) with reduced sediment and runoff trapping capacity (Than Van).

The tree–vetiver barrier design (Than Van village) demonstrated reduced runoff and soil loss in industrial tree plantations and the PSCP's *A. mangium* plots verified improved soil fertility (Cuc, 1996). However, the PSCP's models were not adjoined with any implementation of extension services or specific policies to promote sustained forest floor management.

Costs

The PSCP estimated the establishment cost of vetiver barriers (Than Van village) in the first year as US$ 334 ha^{-1}, including costs of grass clumps, management, fertilizer and labour. During the second year, additional inputs of fertilizer and weeding would cost US$ 76 ha^{-1}. During the following six-year cycle, labour inputs to prune grass barriers were estimated to cost US$ 15 ha^{-1} $year^{-1}$. The total non-discounted costs would thus be US$ 500 ha^{-1}.

Did the PSCP's vetiver barrier design perform sufficiently well to pay back a loan?[5] The break-even point of financial benefits that must be gained during an eight-year rotation period can be estimated from Dixon *et al.* (1989):

$$A = P\left[r(1+r)^n\right] / \left[(1+r)^n - 1\right]$$

where A = annuity value (equal payments over n years), P = lumped sum spent today to be repaid over n years, r = interest rate,[6] n = number of years over which loan is repaid.

[4]Thinned and pruned tree branches were commercially sold to brick factories (Rambo *et al.*, 1996).

[5]Credits related to industrial tree crop plantations were transferred on commercial bank loan principles (interest rate related to total biomass output).

[6]Estimated social discount rate is used in contrast to the prevailing interest rates in financial analysis (Tietenberg, 1992). The financial interest rate exceeded 3 per cent per month on loans from the Agricultural Bank in the study area in the early 1990s (Rambo, 1999; pers. comm.).

Table V. Cost estimates of selected vegetative barrier designs* in the study area (1994 prices)

	US$ ha^{-1}		
	(A) PSCPs Vetiver barrier design	(B) Farm-oriented Vetiver barrier design	(C) Farm-oriented barrier design with *T. candida*
Management operations			
1st year: seed/grass		110	$10 \times 0.73\,kg^{-1}$
fertilizer		$40 \times 0.16\,kg^{-1}$	$40 \times 0.16\,kg^{-1}$
management		10 md × 2·20	10 md × 2·20
planting		20 md × 0·73	20 md × 0·73
Subtotal	334	153	50
2nd year: fertilizer		$20 \times 0{\cdot}16\,kg^{-1}$	$20 \times 0{\cdot}16\,kg^{-1}$
pruning		20 md × 0·73	20 md × 0·73
Subtotal	76	18	18
3–8 year: fertilizer	—	—	—
pruning	6 yr × 15	6 yr × 20 md × 0·73	6 yr × 20 md × 0·73
Subtotal	90	88	88
Total	500	259	156
Total discounted costs†			
($n = 8$; $r = 10\%$)	1072	555	334
($n = 8$; $r = 15\%$)	1530	792	477
($n = 8$; $r = 20\%$)	2150	1114	671
Potential curement quotient per US$ 100 000 ($n = 8$; $r = 10/15/20\%$)	93/65/47 ha	180/126/90 ha	299/210/149 ha

*Assumptions: slope = 20%; vertical interval between barriers = 1·5 m; short-rotation tree plantation ($n = 8$ years); barriers in all alternatives occupy 15% of total area; excluding costs for initial mechanical land preparation.
†n = time period (years), r = interest rate, md = man-days.
US$ 1 = 10 900 VN dong.

A financial break-even point would exist if the average annual gain in revenues from the PSCP design, during an eight-year tree rotation period and a 10 per cent discount rate, equalled US$ 94. This would imply an annual average increase in growth rate of $4{\cdot}1\,m^3\,ha^{-1}$, assuming an estimated wood price of US$ $23\,m^{-3}$ at the Vinh Phu Pulp and Paper Mill. Forest Inventory and Planning Institute (1990) assessed the mean annual increment[7] in volume growth of *E. camaldulensis* in Vinh Phu as $12\,m^3\,ha^{-1}$. No data existed to verify if the PSCP's vetiver barrier design would yield sufficient increase in growth to meet the financial break-even criteria. It is noted that on a 20 per cent steep slope some 15 per cent of the total area would be covered with vetiver barriers and therefore reduce tree density compared to non-treated land.

Estimated operational and management (O&M) costs of three different vegetative barrier approaches are presented in Table V. The approach in (A) reflects the PSCP's tree–vetiver barrier design in Than Van. Cost estimates were based on records from the PSCP's technical staff. Noteworthy is that the estimated O&M costs in (A) were of the same order as the calculated costs to build and maintain bench terraces in Indonesia (Graaf, 1993). The management and implementation in (A) were assumed to be done by Vinh Phu Service Union technicians. (B) illustrates a client-responsive approach where seeds/plants were distributed to farmers and farmers' labour costs were equivalent to an opportunity cost of a forest worker's daily salary. During the establishment phase of (B) it is assumed that farmers were supported by public extensionists.

[7]Maximum and minimum annual increments of *E. camaldulensis* were 18·33 and $4{\cdot}97\,m^3\,ha^{-1}$.

Figure 11. On-farm trial with *T. candida* as vegetative barriers.

Approach (C) includes *T. candida* (Figure 11), used in similar tree-barrier interfaces as in (A) and (B). It was assumed that *T. candida* seedlings received an equivalent fertilizer dosage as the vetiver grass in (B), but having a different N:P:K ratio. Cost estimates in (C) were reiterated from Ham (1991; FRC, personal communication).

In (A) and (B), vetiver grass was planted in ditches (40 $\times$ 40 cm) with a within-row spacing of 15 cm and pruned annually to increase tillering capacity and to produce denser barriers. In (C) seeds of *T. candida* plus fertilizer were placed in contoured furrows at the onset of the rainy season. It was estimated that barriers were cut three times the first year and two times during the second year. Pruned material could be mulched on cultivated land but the related benefits of doing so were not assessed. From the third year and onwards it was assumed that *T. candida* was mostly used as fuelwood.

Table V includes a sensivity analysis using different social discount rates (10, 15 and 20 per cent). Higher rates reflect less societal preferences in future benefits relative to present consumption compared to lower discount rates. Even if non-direct monetary and non-monetary benefits were not included in the assessment it is obvious that (A) would be costly and not likely to spread voluntarily onto farmers' land. Assuming the specified operational costs in (A) are sufficiently accurate, the discounted cost to cover 100 ha of degraded land equalled US$ 107 000 (eight-year rotation period with an annual interest rate of 10 per cent). The equivalent costs to cover 100 ha of degraded land in (B) or (C) were US$ 55 500 and US$ 33 400 respectively. The result in (A) was probably distorted by unjustified high nursery costs and excessive fertilizer dosages (records from the first year, at prevailing retail prices, corresponded to a dosage of 113 kg NPK ha^{-1}).

It may be argued that the vegetative barriers in (A), (B) and (C) could have a longer economic life than an estimated eight-year rotation period. However, the eventual surplus life-length within a continuous short-rotation tree management system is uncertain in all cases. The PSCP staff considered that ripping by machinery was a prerequisite prior to any re-/afforestation operations. Within such a forest land management system, it is doubtful whether the barriers could be kept and maintained independently from the tree crop production cycles. Table V illustrates the comparative discounted costs during a full tree crop production cycle, therefore the actual life-lengths of the vegetative barriers are not considered.

Is The Vetiver Barrier Approach a Universal Winner?

Garrity and Ragland (1993) reported that the grass barrier approach entailed two specific problems. First, farmers had difficulties in trimming tall, prostrated grass species frequently enough to reduce light competition between grass and adjoining crops. Second, grass species with high biomass production increase the risks of competition for nutrients and water with adjoining crops. They further noted that vetiver grass must be planted from vegetative slips, a laborious method for most small-scale farmers. An alternative approach on Southeast Asian sloping land would be to use native weedy grass species like *Imperata cylindrica*, *Paspalum conjugatum*, *Chrysopogon aciculatus* and others as vegetative barriers. Mwanza (1992:12) cited the FAO soil scientist David Sanders who claimed that vetiver grass is not

> a general panacea as some of its more enthusiastic exponents would have us to believe. Soil erosion cannot be treated in isolation. Erosion is a symptom of incorrect land use and poor soil management—problems that can only be solved by the introduction of improved management techniques.

Sanders gave examples from the Comoro Islands, Haiti, Reunion Island, Indonesia and India where vetiver barriers have not been successful due to pest habitat and uprooting induced by volatile oil production. Farmers tend to value vegetative barriers as more attractive if they produce direct household benefits (Mishra *et al.*, 1997). They found that farmers in India preferred *Dichantium annulatum* rather than *V. zizanioides* as the former species is a superior forage resource.

Participatory farming research in Phuong Linh village (Thanh Ba District) in Vinh Phu by the NISF (2001) concluded that among the surveyed[8] group of 40 farmers a majority preferred pineapple or *T. candida* rather than vetiver grass as hedgerow barriers.

The author is left with an impression that the institutional promotion of vetiver grass in the study area is not sufficiently anchored in verifiable and interdisciplinary scientific research. For example, Phien and Tam (2000) concluded from an on-farm experiment done by the NISF (2001) with different hedgerow cropping systems in Than Ba District (Phu Tho[9] Province) that vetiver grass had the best erosion control effect and resulted in the highest crop yields. However, the results from the 1996–98 experiment showed that treatments 6 (pineapple plus vetiver grass) and 3 (pineapple) resulted in higher crop yields than the vetiver grass barrier (Table VI). Likewise, the pineapple barrier had the lowest average soil loss but not significantly different than in the other barrier treatments ($p < 0{\cdot}05$).

Vetiver barriers on flat-gentle slopes in India had an estimated cost of US$ 18 ha^{-1} in 1990, if implemented by the farmers themselves (Brandon *et al.*, 1993). Vetiver grass barriers in China in the early 1990s, including nursery production and on-field O&M, would cost approximately US$ 200 ha^{-1} (National Research Council, 1993). It is not known whether these estimates reflect real prices (adjusted from any price distortions) or not.

The results in Table V indicate that a further expansion of approach (C) would be attractive. Several studies have verified the potential to improve soil fertility on acid, infertile upland soils using *T. candida* as hedgerow/fallow/mulch (Nguyen and Thai, 1993; Pintarak *et al.*, 1996; Hoang Fagerström *et al.*, 2001). Results from the FRC–International Board for Soil Research and Management plots on eroded Plinthic Acrisol ($s = 10$ per cent) in Tam Dao indicated that *T. candida* hedgerows could substantially reduce soil loss compared to bare control plots and improve cassava yields (Phien and Dan, 1994). Thus, a combination of *T. candida* barriers and mulch transfer could improve N availability and crop yields in, for example, enriched fallows in traditional upland agriculture and yield shade to young tea/coffee/cinnamon plantations. The *T. candida* is a deep-rooted shrub therefore it is likely that it will improve soil physical condition on degraded soils.

However, negative food crop barrier interactions may occur from the second year onwards, particularly during low rainfall periods if the shrubs are not regularly pruned (Thai *et al.*, 1994). Further, if *T. candida* is used as a hedgerow/mulch transfer system labour input will increase substantially and net return to labour is not competitive if natural fallow systems are still viable (Hoang Fagerström *et al.*, 2001).

Neither *T. candida* nor vetiver grass are suitable species to improve fodder production in the Midlands as the leaves are non-palatable (Smyle and Magrath, 1993; FRC, 1994b). The specific traditional home garden model that

[8]The study does not explicitly inform whether rate of adoption was measured as true records of field implementation or just interviewee's opinions.
[9]Vinh Phu Province in pre-1996 Vietnam.

Table VI. Total peanut pod yields (1st and 2nd crops) and soil loss as a function of on-farm experiments with hedgerow barriers in Thai Ninh District, Phu Tho Province* during the 1996–98 period

Treatments†	Dry pod yields (kg ha^{-1}) 1st and 2nd crops					Soil loss (t ha^{-1})				
	1996	1997	1998	1996–98 (average)	1996–98 (%)	1996	1997	1998	1996–98 (average)	1996–98 (%)
1. Farmers' practice	1484	1395	1475	726	100	60·7	12·5	9·6	27·6	100
2. NP fertilizer	2000	2400	1506	984	135	48·6	11·2	5·8	21·9	79
3. PB + NPK fertilizer + Lime	2801	3114	2122	1340	185	31·2	5·2	2·1	12·8	36
4. VB + NPK fertilizer + Lime	2869	2487	1794	1192	164	33·0	4·1	3·2	13·4	49
5. TB + NPK fertilizer + Lime	2443	2536	1884	1144	158	35·6	4·3	3·4	14·4	52
6. PVB + NPK fertilizer + Lime	2636	2929	1966	1255	173	42·2	2·7	2·5	15·8	57
7. PTB + NPK fertilizer + Lime	2394	2520	1830	1124	155	39·2	5·8	3·8	16·3	59
8. LGB + NPK fertilizer + Lime	2482	2922	1888	1215	167	45·4	11·7	4·2	20·4	74
Rainfall (mm)						2152	1695	997	1615	

*Vinh Phu Province in pre-1996 Vietnam.
†Fertilizers: NP = nitrogen + phosphorus, NPK = nitrogen + phosphorus + potassium; Hedgerow treatments: PB = pineapple barrier, VB = vetiver barrier, TB = *Tephrosia candida* barrier, PVB = pineapple + vetiver barrier, PTB = pineapple + *T. candida* barrier, LGB = local grass barrier.
Source: Modified from NISF (2001).

has evolved over centuries in the Midlands, the Ruong (forest), Vuon (garden), Ao (fishpond) and Chuong (livestock), frequently includes both fish raising and livestock. Fodder production therefore has to be diversified, incorporating both starch-based crop residues (e.g. cassava) and high-protein legumes (e.g. *Glircidia* sp.). It may be argued that improved forage production on surrounding fertile land in combination with effective governance of forest hillslopes would reduce pressure on forest floor resources. The FCP–PSCP did not effectively address the links between land degradation, animal husbandry and forest floor management until the launch of the Farm-Level Forestry Project. It is hypothesized that this redirection in the work, in combination with a change in Vietnamese land allocation policies (securing long-term users and transfer rights of agricultural and forest land) contributed more to the 're-greening' of the Midlands than any technical SWC designs introduced by the PSCP themselves. The PSCP's vetiver barrier approach (A) was actually devoid of any further expansion onto farmers' land simply by not being competitive or sufficiently flexible to alternative solutions given by the new institutional settings. This is not to say that *V. zizanioides* does not fit into the rural landscape of the Midlands. Rather it shows that the vetiver barrier approach did not explicitly solve the pressure on resources dilemma.

INSTITUTIONAL CHANGES AND FOREST LAND ALLOCATION POLICIES

The PSCP's 'plantation' component included significant achievements such as increased tree canopy cover and improved wood demand–supply balance of raw material to the Vinh Phu Pulp and Paper Mill. However, the efficiency of the project's 'soil conservation' component was less successful for a number of reasons. The degree of success of implementing SWC was constrained by (1) institutional weaknesses in the Vinh Phu Service Union and PSCP organizations, (2) the strong and one-sided emphasis on forestry-based activities already outlined in the original programme document, thereby seriously reducing the analytical framework in which causes of land degradation, including agroecosystems, could be effectively reviewed and understood (Interforest, 1991) and (3) the mere complexity of the FCP spanning over an area characterized by great ecoregional diversity and rapidly changing institutional and economic environments.

The PSCP was an administrative unit within the government organization Vinh Phu Service Union where both represented dual-edged interests in times of institutional and economic transitions. The Vinh Phu Service Union was the Ministry of Forestry's representative to assist in the implementation of the FCP, but also acted as a profit-making state-owned enterprise within the new economic reforms of Doi Moi[10] (Mid-Term Review, 1994). The PSCP had commercial interests in the SFEs, which were successively transferred to provincial and village authorities. In 1994 the government launched a re-/afforestation programme (Decree 327 projects) to colonize 'barren lands'[11] managed by provincial and village institutions and only six SFEs were still managed by the PSCP (Fox and Donovan, 1997). Both the Vinh Phu Service Union and PSCP faced reduced importance of partnership within the FCP. These changing institutional scenarios may help to explain why the PSCP staff had difficulties being client-oriented in designing project policies and barrier approaches. For example, Stocking and Abel (1992) estimated that labour inputs at an experimental SWC site[12] in Vinh Phu in the early-1990s, designed by Vinh Phu Service Union-FRC, equalled some 1500 workdays. Despite the launch of new land allocation policies in Vietnam the PSCP was still addressing 'old' issues on state forest land. At village-level forest land allocation proceeded through the distribution and administration by the People's Committees. Comparative research done in the Vinh Phu during the early-1990s found that the People's Committees became powered to allocate land to individuals from either former co-operatives or SFEs (Romm and Sy, 1996). Official land taxation on allocated forest land was fixed at 4 per cent of total product value (Cuc *et al.*, 1996), but the local taxation costs were settled from negotiations between the land management unit of the People's Committee and the individual households. Field research in 1994 in Doan Hung and Than Hoa Districts revealed that many villagers did not know the rates of repayment. The People Committee's representatives in Than Hoa District stated that there would be an 18–20 per cent tax on the second rotation of industrial tree crop plantations (Rambo *et al.*, 1996). Thus, forest land taxation policies at the village level created uncertainty in management decisions and unwillingness to invest in land restoration techniques.

Serious delays in the release of government funds to the PSCP further aggravated the capacity to implement watershed rehabilitation works. In fact, it may be argued that the PSCP was never authorized and organized to design barrier systems that could alleviate the heavy pressure on forest resources in the Midlands. The PSCP tree–vetiver barrier models were doomed to be efforts in splendid isolation as long as the FCP had a strong focus on producing industrial pulpwood on degraded land, but lacking the institutional environment to ensure long-term users' rights arrangements and appropriate legal enforcement capacity if regulations were violated.

The Mid-Term Review (1994: 37) concluded that the accounting and financial management systems in use 'did not meet the demands of any of the actors in the programme'. In combination with a lack of client-oriented objectives, this probably influenced the PSCP to design models with a 'disbursement goal' rather than optimizing resource-use efficiency.

The Land Law of 1993 made attainable the farmers' interest in using land resources more productively. However, the usufruct certificates issued to individual households also included restrictions by the state about what crops to grow at specific sites. For example, farmers were sometimes not permitted to plant anything else other than tree species on former state forest land (Ngyuen, 1994, unpublished paper). This reduced the flexibility of the land allocation policies, as farmers were not able to adjust their land use according to their local needs within the upland ecosystems or to initiate experiments with barrier/improved fallow/mulch designs.

[10]Literally translated as 'change' and 'newness', the Vietnamese Communist Party's term for reform and renovation in the economy launched at the Sixth National Congress in 1986.
[11]Decree 327 described barren lands as unoccupied land, barren hilly areas, forests, denuded beaches and waterfronts. Land was classified as 'barren' if actual use did not coincide with its designated use (Sikor, 1995).
[12]This presumably refers to a combined *T. candida* barrier-bench terracing approach in Phu Tho District visited by the author in 1990–91.

CONCLUSIONS

The PSCP addressed land degradation in the study area from a technical and sectoral standpoint. Rehabilitation was assumed to start from re-/afforestation of severely degraded microcatchments (mainly former SFEs) with mixed tree–vetiver barrier designs. A few model areas were established during 1990–94, interpreted as technical designs from which farmers should absorb management principles and spontaneous adoption.

From a technical viewpoint, the PSCP's tree–vetiver barrier designs demonstrated that the grass component may well be ecologically adapted to the Midlands and be efficient to: (1) stabilize the soil by root mass, (2) retard and filter sediment and runoff through permeable barriers and (3) provide mulch transfer systems. The author concluded that the hydraulic efficiency to filter and retard runoff and soil loss was reduced on degraded Ferric-Plinthic Acrisols steeper than 15 per cent. It is further noted that nutrient leaching causes significant positive fertilization effects on vetiver grass strips at downslope sections of the investigated microcatchments. Unfortunately, the experimental designs at the pilot sites did not include any comparative assessments of alternative vegetative barrier approaches. It was also determined that degraded Ferric-Plinthic Acrisols ($s > 15$ per cent) would need a combined approach of stone check dams and vegetative filters, as rill and gully erosion processes were seen to be major sources of sediment flux, nutrient leaching and runoff from the investigated microcatchments. Despite heavy fertilizer dosage, it was apparent that the vetiver barriers performed poorly on steep (30–40 per cent slope) degraded Ferric-Plinthic Acrisols.

The increased interest among farmers to diversify tree-based land use may have added significant, but non-recorded, vegetative filters to retard soil loss and runoff at the landscape scale and therefore—in accordance with findings by Van Noordwijk *et al.* (1998)—contributed more to sediment captured than SWC works at the field scale.

The author did not recognize any voluntary spread of the PSCP's tree–vetiver barrier designs to hill lands. In contrast, it was observed that individual households started to diversify tree species selection in relocated *Eucalyptus* plantations. This may have been in response to improved household governance of forest hill land due to changes in land allocation policies and a more client-oriented extension service by the FCP. The Farm Level and Forestry Project gave significant support to individual farmers and families, e.g. distributing tree seedlings and forest management training. The PSCP tried to survive but faced an increasingly difficult situation following the launch of Doi Moi and redirected FCP policies to support individual farmers rather than state forest units.

This study highlights a comparatively low cost-effectiveness in the PSCP's tree–vetiver barrier models, mainly due to distorted nursery costs and a strong dependency on public extension work. The author concluded that it was unlikely that the vetiver barriers would yield direct-benefits, e.g increased annual tree growth rates, that would outweigh the costs of establishment, operation and maintenance. It was further noted that neither the inclusion of vetiver grass nor local leguminous trees/shrubs in forest hill slope management would be significant 'land savers' as long as the encroachment of forest floors continued indiscriminately.

Vocabulary in the original project documents, e.g. 'Raw Material Area', symbolizes that the evolution of the FCP took a dramatic but slow move from an initial 'forest plantations are a God send' approach to a more realistic insight where land rehabilitation strategies must include institutional and legislative reforms. These experiences show that public- and project-driven soil and water conservation strategies will not achieve any miracles in terms of rehabilitated land in the Midlands, if not the institutional settings effectively guarantee long-term accountability between the state, village institutions and individual farmers, thereby giving incitements to break the chain of forest floor depletion and non-sustainable organic matter removal practices in the study area.

ACKNOWLEDGEMENTS

This study was partially supported financially by a grant from the Royal Swedish Academy of Agriculture and Forestry ('KSLAs samordnade fond'), which is here acknowledged.

Field visits in Vinh Phu Province, Vietnam, were made possible due to assignments by the Swedish-Vietnamese Co-operation Programme through Jaakko Poyry Consulting, Stockholm, Sweden. Personnel at the Plantation and

Soil Conservation Project (PSCP) and the Forest Research Centre (FRC), Phu Tho, Vinh Phu Province, were of great support during my visits in the study area, as well as numerous staff members at the Ministry of Forestry and various research institutes in Hanoi.

An earlier draft of this paper has been critically reviewed by Carl Christiansson, Peter Schlyter and Annika Dahlberg, Department of Physical Geography and Quaternary Geology, Stockholm University. Likewise, Terry Rambo, East–West Center, Honolulu, HI, USA, has added valuable information regarding farmers' conditions in the study area during the early 1990s.

REFERENCES

Brandon C, Ramankutty R. 1993. Toward an environmental strategy for Asia. World Bank Discussion Papers No. 224. The World Bank: Washington, DC.

Bregman L. 1993. Comparison of the erosion control potential of agroforestry systems in the Himalayan region. *Agroforestry Systems* **21**: 101–116.

Brown SML, Mo J, Kong G. 1995. Structure and organic matter dynamics of a human-impacted pine forest in a MAB reserve of subtropical China. *Biotropica* **27**: 276–289.

Cramb RA, Nelson RA. 1998. Investigating constraints to the adoption of recommended soil conservation technology in the Philippines. In *Soil Erosion at Multiple Scales*, Penning de Vries FWT, Agus F, Kerr J (eds). CAB International: Wallingford; 99–120.

Cuc LT. 1995. Forest ecosystem and Swidden agriculture in uplands of northern Vietnam. In *Proceedings of the Regional Seminar—Workshop on Tropical Forest Ecosystems Research, Conservation and Repatriation*, Sorensen KW, Enriquez GL, Umaly RC, Kartana JT (eds). *Biotrop Special Publication* 55. SEAMEO BIOTROP: Bogor; 269–289.

Cuc LT. 1996. Approaches to rehabilitating degraded lands in the Midlands. In *Red Books, Green Hills: The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam*, Cuc LT, Rambo AT, Fahrney K, Vien TD, Romm J, Sy DT (eds). Program on Environment, East–West Center: Honolulu; 23–36.

Cuc LT, Gillogly K, Rambo AT. 1990. Agroecosystems of the Midlands of northern Vietnam. East–West Center, Occasional Paper No. 12. Environment and Policy Institute, East–West Center: Honolulu.

Cuc LT, Sikor T, Rucker M. 1996. Implementation of economic reform in Doan Hung and Thanh Hoa. In *Red Books, Green Hills: The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam*, Cuc LT, Rambo AT, Fahrney K, Vien TD, Romm J, Sy DT (eds). Program on Environment, East–West Center: Honolulu; 47–71.

Dalton PA, Smith RJ, Truong PNV. 1996. Vetiver grass hedges for erosion control on a cropped flood plain: hedge hydraulics. *Agricultural Water Management* **31**: 91–104.

De Koninck R. 1999. *Deforestation in Vietnam*. International Development Research Centre (IRDC): Ottawa.

Dixon JA, James DE, Sherman PB. 1989. *The Economics of Dryland Management*. Earthscan: London.

Donovan D. 1997. Development in the local context: case studies from selected hamlets in five northern Provinces. In *Development Trends in Vietnam's Northern Mountain Region. Volume 2. Case Studies and Lessons from Asia. East–West Center/Center for Natural Resources and Environmental Studies/Vietnam National University, Hanoi*, Donovan D, Rambo AT, Fox J, Cuc LT, Vien TD (eds). National Political Publishing House: Hanoi; 1–112.

Fahlén A. 1991. *Thoughts on Soil and Water Conservation Research and Development Work in the Future Forestry Cooperation Programme 1991–96 in Northern Vietnam.* Project Document. Plantation and Soil Conservation Project. Interforest AB: Stockholm.

Fahlén A. 1994. *Assessment of Soil and Water Conservation Activities in the Forestry Development Area In Northern Vietnam*. Final report. Jaakko Pöyry Consulting AB: Stockholm.

FAO-Unesco. 1988. *Soil Map of the World.* Revised legend. FAO-Unesco: Rome.

FIPI. 1990. *Results of Forest Inventory of the Raw Material Area Related to Vinh Phu Pulp and Paper Mill.* Ministry of Forestry/Forest Inventory and Planning Institute: Hanoi.

Fox J, Donovan D. 1997. Social forestry and institutional in upland development: lessons from Asia. In *Development Trends in Vietnam's Northern Mountain Region. Volume 2. Case Studies and Lessons from Asia*, Donovan D, Rambo AT, Fox J, Cuc LT, Vien TD (eds). *East–West Center/Center for Natural Resources and Environmental Studies/Vietnam National University, Hanoi*. National Political Publishing House: Hanoi; 113–142.

FRC. 1992. *Forest Research Newsletter, No 2, November 1992*. Forest Research Centre: Bai Bang, Vinh Phu; 3–4.

FRC. 1993. *Forest Research Newsletter, No 4, July 1993*. Forest Research Centre: Bai Bang, Vinh Phu; 19, 21.

FRC. 1994a. *Forest Research Newsletter, No 5, March 1994*. Forest Research Centre: Bai Bang, Vinh Phu; 3–6.

FRC. 1994b. *Farming Systems on the Uplands. Survey and Research Results in the Forestry Development Area*. Forest Research Centre: Bai Bang, Vinh Phu.

Garrity DP, Ragland J. 1993. Sustainable land-use systems for sloping uplands in Southeast Asia. In *Technologies for Sustainable Agriculture in the Tropics. ASA Special Publication* 56, Lal R, Ragland J (eds). American Society of Agronomy: Madison, WI; 41–66.

Garrity DP, Mercado A Jr, Stark M. 1998. Building the smallholder into successful natural resource management at the watershed scale. In *Soil Erosion at Multiple Scales*, Penning de Vries FWT, Agus F, Kerr J (eds). CAB International: Wallingford; 73–82.

Graaf J. 1993. *Soil Conservation and Sustainable Land Use*. Royal Tropical Institute: Amsterdam.

Ham KV. 1991. Annual plan of operation 1992. Plantation and soil conservation project, Vietnam-Sweden Forestry Cooperation Programme. *Project Document.* $S_{jpqv/fcp}$*-08, 1991-09-27*. Interforest AB: Stockholm.

Hoang Fagerström MH, Van Noordwijk M, Phien T, Vinh NC. 2001. Innovations within upland rice-based systems in northern Vietnam with *Tephrosia candida* as fallow species, hedgerow, or mulch: net returns and farmers' response. *Agriculture, Ecosystems and Environment* **86**: 23–27.

Interforest. 1991. Sweden-Vietnam Forestry Cooperation Programme 1991–1996. *Programme Document. Revised 1991-04-01*. Interforest AB: Stockholm.

Khoa LV. 1991. Incorporating land-use into soil fertility conservation and environmental protection in the Midlands of northern Vietnam. In *National Seminar on Setting Priorities for Research in the Land Use Continuum in Vietnam, 9–13 September, 1991, Hoa Binh*. IIED/SIDA/FSI: Hanoi; 120–130.

Lanh LV. 1994. Establishment of ecological models for rehabilitation of degraded barren midland land in northern Vietnam. *Journal of Tropical Forest Science* **7**: 143–156.

MacDicken KG. 1990. Agroforestry management in the humid tropics. In *Agroforestry: Classification and Management*, MacDicken KG, Vergara NT (eds). Wiley: New York; 99–149.

Mid-Term Review. 1994. Vietnam-Sweden Forestry Cooperation Programme. *Mid-Term Review.* SIDA: Stockholm.

Mishra VK, Ranade DH, Gupta RK. 1997. Comparative evaluation of vegetative soil and water conservation measures based on overall performance index. *Indian Journal of Soil Conservation* **25**: 103–105.

Mo J, Brown S, Lenart M, Kong G. 1995. Nutrient dynamics of a human-impacted pine forest in a MAB reserve in subtropical China. *Biotropica* **27**: 290–304.

Mwanza F. 1992. Vetiver: 'miracle grass' or oversold cure-all? *Ceres. The FAO Review No. 136* **24**: 4 Jul–Aug; 11–12.

NISF. 2001. Farmer participatory research and technology transfer on sloping lands in northern Vietnam. *Final Report for Phase II (1st April 1998 to 30th March 2001)*. (National Institute for Soil and Fertilizers: Hanoi.

National Research Council. 1993. *Vetiver Grass: A Thin Green Line against Erosion.* National Academy Press: Washington, DC.

Népote J, Guillaume X. 1992. *Odyssey Illustrated Guide to Vietnam*. Guidebook Company: Hong Kong; 90.

Nguyen TS, Thai P. 1993. *Tephrosia candida*: a soil ameliorator in Vietnam. *Contour Jakarta* **5**: 27–28.

Pandey S, Lapar MAL. 1998. A microeconomic analysis of adoption of contour hedgerows in the Philippine uplands. In *Soil Erosion at Multiple Scales*, Penning de Vries FWT, Agus F, Kerr J (eds). CAB International: Wallingford; 83–98.

Phien T, Dan NT. 1994. *Land Degradation and Cultivation Measures on Sloping Lands for Sustainable Agriculture.* National Institute for Soils and Fertilizers: Hanoi.

Phien T, Tam TT. 2000. Vetiver grass in hedgerow farming systems on sloping lands in Vietnam. *Contour* **XII**: 2. ASOCON Newsletter: Jakarta; 29–32.

Pintarak A, Juntorn W, Turkelboom F, Van Look RK, Van Keer K. 1996. Highland farming: soil and the future? *Proceedings of a Conference, Chiang Mai, Thailand: Soil Conservation Project, Mae Jo University, Thailand-Catholic University of Leuven, Belgium, 21–22 December 1995*; 177–187.

Rambo AT. 1995. Defining highland development challenges in Vietnam. In *The Challenges of Highland Development in Vietnam*, Rambo AT, Reed RR, Cuc LT, DiGregorio MR (eds). Program on Environment, East–West Center: Honolulu; xi–xxvii.

Rambo AT, Fahrney K, Worachai L. 1996. Household ecology and economy in Doan Hung and Thanh Hoa. In *Red Books, Green Hills: The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam*, Cuc LT, Rambo AT, Fahrney K, Vien TD, Romm J, Sy DT (eds). Program on Environment, East–West Center: Honolulu; 57–71.

Romm J, Sy DT. 1996. The impact of economic liberalization on the people and environment of Lap Thach District. In *Red Books, Green Hills: The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam*, Cuc LT, Rambo AT, Fahrney K, Vien TD, Romm J, Sy DT (eds.) Program on Environment, East–West Center: Honolulu; 75–109.

Sehgal J. 1989. Classification and correlation of the Vietnamese soils. A Technical Report. Project VIE 86/024. FAO-UNDP: Hanoi.

Siem NT, Phien T. 1994. Monitoring of soil environment within the Forest Development Area (FDA). *Forest Research Newsletter, 5, March 1994.* Vietnam-Sweden Forestry Cooperation Programme, Forest Research Centre: Bai Bang, Vinh Phu; 33–34.

Siem NT, Phien T. 1995. Acid upland soil in Vietnam and their management for agriculture. In *Plant Soil Interactions at Low pH*, Date RA, *et al.* (eds). Kluwer-Academic: Amsterdam; 771–774.

Sikor T. 1995. Decree 327 and the restoration of barren land in the Vietnamese Highlands. In *The Challenges of Highland Development in Vietnam*, Rambo AT, Reed RR, Cuc LT, DiGregorio MR (eds). East–West Center: Honolulu; 143–156.

Simpson JA. 1990. Assessment of the soils and nutrition of Eucalypt and Acacia plantations for the Vinh Phu Project in the Socialist Republic of Vietnam. *Final Report*. Interforest AB: Stockholm.

Smyle JW, Magrath WB. 1993. Vetiver grass—A hedge against erosion. In *Technologies for Sustainable Agriculture in the Tropics*, Lal R, Ragland J (eds). ASA Special Publication 56. American Society of Agronomy: Madison, WI; 109–122.

Stocking MA, Abel N. 1992. Labour costs: a critical element in soil conservation. In *Soil Conservation for Survival*, Tato K, Hurni H (eds). Soil and Water Conservation Society: Ankeny, IA; 206–250.

Tap Ban Do Viet Nam. 1986. Tap Ban Do Viet Nam Hanh Chinh Va Hinh (The map of Vietnam). 1:500 000. *XB:187/BD/GPNT/XB(1986)*: Hanoi.

Thai P, Nguyen TES, Luong DL, Nguyen VT, Dau CL, Nguyen TD, Sajjapongse A. 1994. *Report of the Annual Review Meeting on Asialand Management of Sloping Lands in Asia, Guiyang, China, 2–8 September 1993.* IBSRAM: Bangkok; 193–216.

Thang NV. 1995. The Hmong and Dzao peoples in Vietnam: impact of traditional socioeconomic and cultural factors on the protection and development of forest resources. In *The Challenges of Highland Development in Vietnam*, Rambo AT, Reed RR, Cuc LT, DiGregorio MR (eds). East–West Center: Honolulu; 101–119.

Tietenberg T. 1992. *Environmental and Natural Resource Economics*. Harper Collins: London.

Van Noordwijk M, Widianto HM, Hairiah K. 1991. Old tree root channels in acid soils in the humid tropics: important for crop root penetration, water infiltration and nitrogen management. *Plant and Soil* **134**: 37–44.

Van Noordwijk M, Van Roode M, McCallie EL, Lusiana B. 1998. Erosion and sedimentation as multiscale, fractal processes: implications for models, experiments and the real world. In *Soil Erosion at Multiple Scales*, Penning de Vries FWT, Agus F, Kerr J (eds). CAB International: Wallingford; 223–253.

Vien TD, Fahrney K. 1996. Overview of the Midlands of Vinh Phu. In *Red Books, Green Hills. The Impact of Economic Reform on Restoration Ecology in the Midlands of Northern Vietnam*, Cuc LT, Rambo AT, Fahrney K, Vien TD, Romm J, Sy DT (eds). East–West Center: Honolulu; 3–22.

Vinh Phu Province (Division of Statistics). 1990. *Area, Population Labour and Land Resources Report. Paper No. 26/12/90.* Division of Statistics: Viet Tri.

Young A. 1985. *Soils Aspect of the Forestry Plantation Programme for the Vinh Phu Paper Mill, Vietnam. Final Report. 001-*V_{qsmv}*-075*. Interforest AB: Stockholm.

Young A. 1989. *Agroforestry for Soil Conservation*. CAB International: Wallingford.

