Deliverable 1.3 - Appendix A3

Conservation agriculture in sloping lands of Vietnam

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I. Concepts and practices

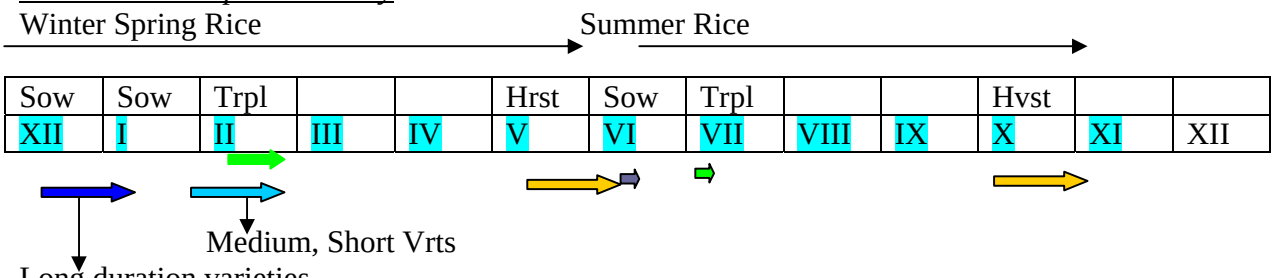
- *Brief on Vietnamese agriculture during last decades*

Vietnam is one of the poorest countries in the world with per capita GNP of about 400 US Dollars. The population is about 80 million. Out of 33.091 million hectares of natural area, only 7.384 million hectares are suitable for agricultural production. With the fast increase in population, the per capita agricultural lands has reduced from 1,318 m^2 in 1980 to 1,080 m^2 in 2000, then to 914 m^2 in 2003. In spite of the limited agricultural lands, the Vietnamese economy is still largely agricultural with 75% of the population living in rural areas and they are mostly dependent on agricultural production.

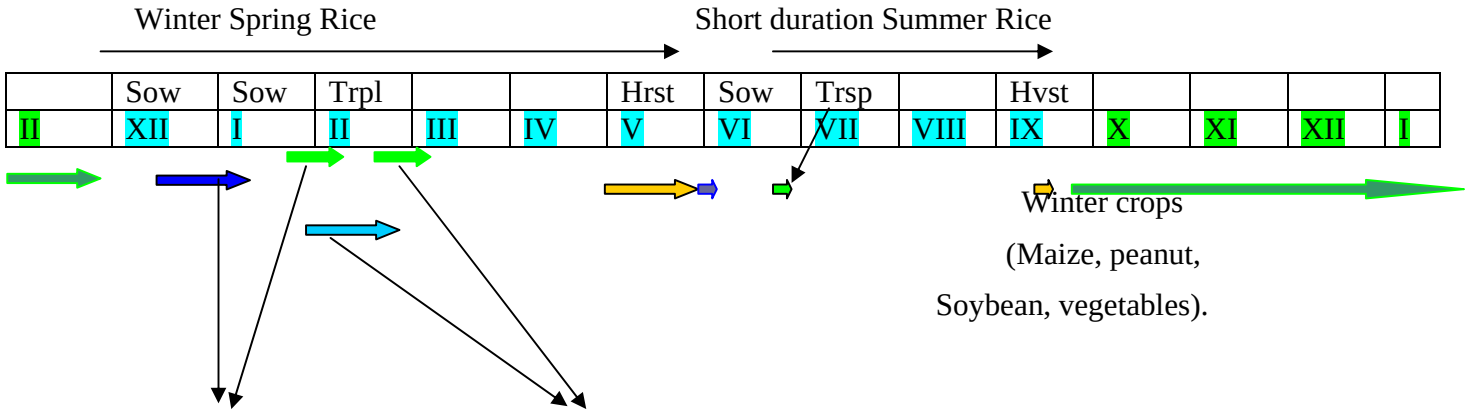
High population density puts much pressure on forest coverage which has been reducing from 14.3 million hectares (45%) in 1945 to 9.3 million hectares (28%) in 1993. At present thanks to common efforts, the forests coverage has increased to 34%. In spite of limited agricultural lands, Vietnamese agriculture has been developing very fast during the last two decades, especially food production. From a country with chronic hunger, Vietnam has become the third world largest rice exporter. In addition, Vietnam is one of the world leading exporters of aquaculture products, coffee, tea, cashew nut and rubber.I.1. Description of cropping patterns Cropping patterns in Vietnam vary widely between lowland and upland, between the South with typically tropical and the North with sub-tropical climates, and of course between different sub-ecological regions. For example, in the South of Vietnam, because the temperature is high year round, farmers can grow even 3 rice crops per year. The big problem there is to arrange suitable cropping seasons to avoid flooding damage. In the North, however, triple rice crops/year is almost impossible because of cold winter, but farmers can grow other winter crops. In mountainous regions, the cropping patterns are still more diverse. In the context of this report we present some typical cropping patterns/ systems by the following figures:

Irrigated rice-based cropping calendar in North Vietnam

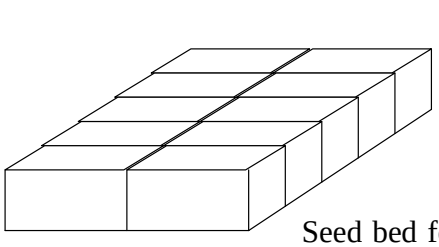
For two rice crop season only

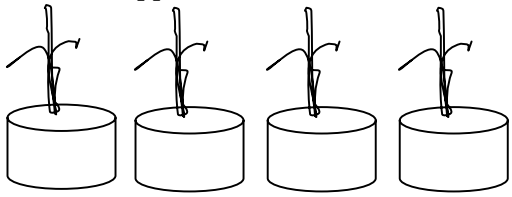


For two rice seasons and one winter season



In case the summer rice cannot be harvested before 15 September, relay cropping for soybean, and pot-sowing-then-transplanting for maize are applied.





Seed bed for maize seedlings made of mud on plat space 15-20 days before harvesting rice (each pot is 5-7 cm thick, 4 x 4 cm wide).

Maize seedlings at 12-15 day age that are ready for transplanting in to newly harvested rice fields by mini-tillage of soil.

For one rice season in Summer in valleys and terraces

(No water or uncertain water supply in Spring season)

Long, medium, short duration rice varieties.

						Sow	Trplant			Hvst	Hvst			
II	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I

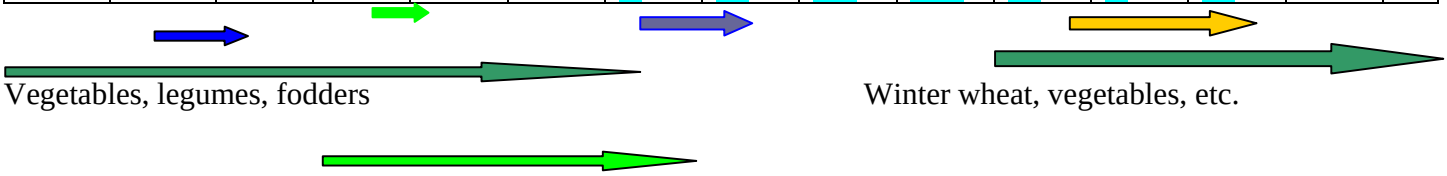
Winter wheat, vegetables, legumes, fodders — Winter crops

Sloping land agricultural production patterns in Northern mountainous regions

Upland Rice based systems

Long, medium, short duration rice varieties.

						D. Sow	D. Sow			Hvst	Hvst	Hvst		
II	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I

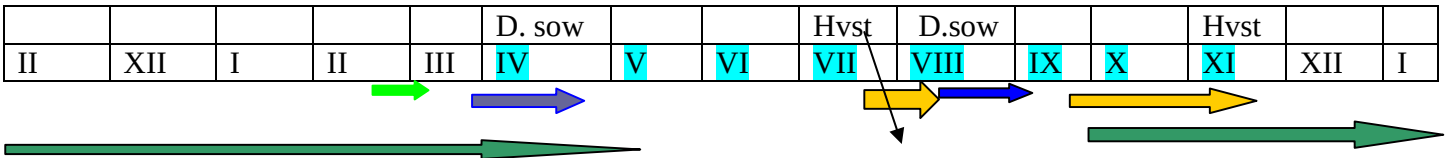


Vegetables, legumes, fodders — Winter wheat, vegetables, etc.

Good time for fodder and mulch production.

Two maize season systems

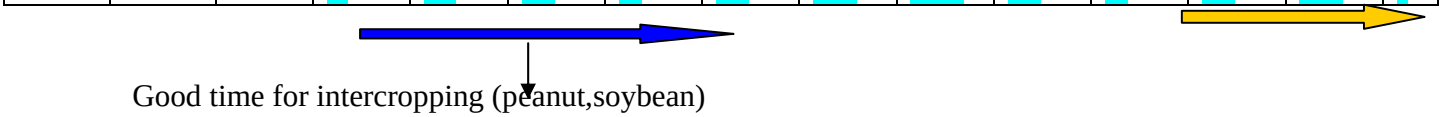
					D. sow			Hvst	D.sow			Hvst		
II	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I



Vegetables, legumes, fodders — Inter- , relay cropping

Cassava based systems

			planting						D. Sow			Hvst	Hvst	
II	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I



Good time for intercropping (peanut,soybean)

Vietnamese government agriculture and rural development orientations

In the recent years, Vietnamese economy has developed at high speeds. In the last two decades, the GDP increase rate remained steadily at 8 to 10% per year, of which food production increased by 4.2% annually. A result, the farmers' living conditions, quality and ecological environment have been dramatically improved. The face of Vietnamese rural areas has been changed. The farming systems have been evolving in more sustainable ways. These achievements are largely thanks to "Renovation" expressed through dramatic changes in policies, institutional and management systems and mechanisms, of which the farmer oriented policies play the most important role in promotion agriculture and rural development. The following are brief description of the government main policy orientations toward sustainable development of farming systems.

- *Development of farm-household economy and agriculture:* Every farm-household is now independent and self-directed economic unit having the rights to decide and implement production plans and enjoy its products or markets.
- *Land allocation:* Land has been allocated to farmers for long-term use. Farmers are encouraged to manage their land in the best ways and reclaim fallow or marginal lands. Farmers have full liberty in decision making on the use of the allocated lands.
- *Land use tax:* Agricultural land use tax has been reduced to minimum. People in remote and isolated areas are exempt from land use tax.
- *Credit for farm-households:* About 3 million poor house-holds gain investment capital from the Government budget. Farmers can borrow money with low or no interest from various rural credit systems.
- *Scientific research, technology development and agricultural extension:* Budget has been greatly increased for scientific research, technology development and agricultural extension.
- *Improvement in circulation and marketing of agro-products:* New markets have been opened, reduced tax on agro-products, new roads have been built or underway to be built, old roads have been upgraded, especially in mountainous and border provinces for circulation of agro-products.
- *Improvement of agro-product quality:* High quality and high cash value species/varieties are promoted through varietal improvement, crop diversification, changing production patterns and promotion of safe food production.
- *Promotion of mountain agriculture and rural development in more sustainable ways:* A state program of science and technology has been launched to help mountainous farmers with more environmental friendly technologies with reducing inputs, but ensuring higher outputs. A new center specialized for agricultural science research and development has been established. The name of this very important center which will be a future regional agricultural science research institute is Northern Mountainous Agricultural Research Center (NOMARC).
- *Promotion of ecologically oriented production approaches:* Resistant varieties, local traditional germplasm, low input technologies are increasingly explored and used. The most important activities are crop diversification, crop rotation, intercropping, growing cover crops for soil protection and production of animal fodder, use of organic manure, soil drying and

aeration, use of alluvial water for irrigation, field sanitation, use biopesticides, light traps, natural predators, building ecological villages, etc.

- Conversion of food crop ineffective land into more economically effective and environment friendly production, for example of aquatic and fruit or industrial products: This has proved the rightness of our government policies on sustainable agriculture and rural development in Vietnam in a long run. Large areas of degraded lands now became fruit orchards, industrial trees plantation, eco-tourism spots, etc. The saline coastal lands, even rocky mountains are converted into aquatic production areas which provide much higher income than planting annual crops.

- Poverty alleviation and hunger eradication: Many state programs have been realized to help poor farmers, especially in mountainous and marginal regions to organize their production and develop off-farm income generation activities. Capacity building, infrastructure construction, public health care, education, social equity, job creation, technical and financial support are some of the core issues of the government policies for poverty reduction and hunger eradication. The major programs are the National Targeted Poverty Reduction and Job Creation Program, Prime Minister's Decisions on Socio-Economic Development in Central Highland, Northern Mountainous and Mekong River Provinces, the Program for Socio-Economic Development in Communes Facing with Extreme Difficulties in Remote and Mountainous Areas (Program 135) and the Program for 5 Mil. ha of Forest Planting.

I.2. Driving forces and constraints to dissemination of alternatives to conventional agriculture

Situation of sloping land management in Vietnam

Mountainous and hilly lands (sloping lands) occupy 3/4 of natural inland territory of Vietnam. In general, these lands are not favorable for agricultural production, especially those being denuded from vegetal cover. Available data show that in the 1940s the forest cover in Vietnam was 45%, then reduced to 25% in the 1980s. Nowadays, thanks to great efforts of Vietnamese people, plus invaluable support from international communities in reforestation, the forest cover has reached 32%. The area of bare hills and lands has reduced from 10 million hectares in the 1980s to 8.5 million hectares in 2003.

Sloping lands are distributed in all 9 ecological regions of Vietnam, but mostly in the Northern mountainous, Central and Tay Nguyen regions. Most of gentle slopes of less than 15^o (accounting for 21.9%) have been used for agricultural and forestry production. The lands with 15^o to 25^o sloppiness occupy 16.4%. The rest 61.7% are very steep (more than 25%). Due to the lack of production lands, mountainous farmers have to cultivate food crops in very steep slopes of more than 25^o. On such slopes, soil erosion occurs at very high speed, so the time for productive cultivation is short, commonly only 2 or 3 seasons of short cycle crops, followed by cassava that is planted as the last crop of a

cultivation cycle. Due to population pressure, the fallow periods are commonly reduced from more than 25 years to 5 and 3 years that are not long enough for soil fertility to be recovered. So, the crop yields are generally low. Most of the gentle slopes have past through too many crop-fallow cycles with soil being reduced after each cycle. On this slopes, the constraints to crops are not only poor nutrition, but also soil toxicity, soil compaction. They are left as bare hills and lands with very poor vegetal cover.

Table 1. Forest coverage over time

Year	Forested area (1000 ha)	Forest coverage (%)
2002	12051.2	36.5
1999	10.92	33.2
1995	9.31	28.2
1990	9.18	27.8
1985	9.90	30.1
1980	10.91	32.1
1976	11.17	33.8
1943	14.3	43.0

(Source: Department of Forest Development, after Vu Tien Hinh, 2003).

As a result of lost forest resources, soil degradation, low crop yield, the lives of the mountainous farmers remain low, and it seems difficult for them to get out of the vicious circle of poverty. Recently, agricultural production in mountainous regions has developed quite fast, but hunger eradication, poverty alleviation and natural resources management in mountainous regions remains a great challenge to our government and people.

New look on sloping lands

In spite of numerous difficulties, sloping lands have great development potential and their role in survival of world humankind is becoming greater and greater, particularly when green house effects come to full expression, i.e. when large plains of river deltas become submerged in the sea water. Then the main sources of production lands are sloping lands. Besides, forests in sloping areas play very important role in climate conditioning. The following are general features of sloping lands:

- Sloping lands are very diverse and fragile eco-systems,
- Sloping lands are the living lands of more and more people,
- Any mistake in management of sloping land contains unexpected consequences that may take place on large scales,

So, sloping lands deserve taking care of and more effective management. In other word, one has to pay more attention to research and application of sustainable technologies to get high but stable yield, at the same time conserving the soil and water resources for long-term purposes. This is not an easy task, but one can fulfill it very well if the land husbandry is seriously dealt with

Perception of sustainability

There are several definitions of sustainability in development, but their common meaning can be shortly summarized as "sustainable development is a kind of development that can meet the demands of present but not damages the ability of the future generations to satisfy their demands too". In order to make agricultural development sustainable, one need to apply integrated cultivation measures so as to meet consumption demands, at the same time preserving lands today to produce food for tomorrow.

For mountainous regions, the development must be linked with conservation of natural resources and environment protection. At the same time, efforts should be concerted to build and strengthen the capacity of local human resources. This report will focus on soil fertility conservation and improvement research and development activities, their results and scale of application in different localities in the Northern mountainous regions of Vietnam. Due to high diversity in natural and socio-economic conditions, the problems are usually complicated and interlinked, so that comprehensive measures must be used to solve them. However, there are common points like soil erosion control, preservation of soil and water sources, improvement of soil fertility for durable agriculture, etc. that can be solved by more or less common methods. And this methods have been jointly researched by CIRAD and its partners in Latin America, Africa, and recently in Asia like Vietnam, Thailand and Laos. In fact, these methods contain feasible techniques for sustainable agriculture in mountainous regions.

Perception on soil fertility

Soil fertility is commonly referred to as the sufficiency of all kinds of nutrients, hence neglecting physical and biological properties that are very important to soil productivity. In our research, due attention has been paid to improvement of biological activity as the soil fauna and microflora play very important role in nutrition recycling and circulation (cellulose decomposition, nitrogen fixation, soil softening, etc.). And the best ways are to: use organic fertilizers; keep soil moisture; protect the soil from erosion by mulch from all sorts of vegetal materials.

Summary of main constraints in the lowlands and general solving approaches

Main problems resulted from conventional agriculture	Main solutions
Yield's ceiling (6-7-8 T/ha)	Use of hybrid seeds, increase land and labor productivity, cropping seasons, etc.
Low income from rice	Increase quality, change cropping patterns (diversification), market products, increase cropping seasons, etc.
Pollution of environment, food safety	Ecological farming: organic fertilizers, resistance to pests and diseases, tolerance adverse conditions, etc.
Soil erosion(100 – 200 T/ha of lost soil)	Soil cover: Direct & indirect cover (Increasing surface biomass), Sustainable sloping lands technologies
Land degradation (8.5 mil.ha of bare hills/lands,	Rehabilitation: Reforestation, cover crops, terrace making
Drought in dry season, flooding in rainy season	Reforestation, Water reservoirs, improving soil infiltration
Weed infestation	Soil mulch, mechanical, herbicide
Low Yield (Maize: 1.5-2.0 T/ha; Upland rice: 0.8-1.5 T/ha; Cassava: 10-14 T/ha).	Introduction of high yielding varieties, including hybrids
Conflict between crop, animal and forest production (free grazing of animals).	Integration of animal fodder into AFsystems, Intensification in lowland to reduce pressure on sloping land

II. Significance and impacts of the results

Lessons leaned form DMC (Direct sowing mulch based cropping systems) research and development in foreign countries

DMC and related techniques have been studied, developed and adopted largely in America. The leading countriesare USA, Brazil, Canada andArgentina. The approximate areas under DMC are indicated in table 2.

Table 2. Area under DMC in the world

Country	Cultivated area (ha)	DMC area (ha)	(3)/(2) %	Note
(1)	(2)	(3)	(4)	(5)
USA	177.000.000	22.410.000	13	
Brazil	53.000.000	17.356.000	33	
Canada	45.000.000	4.080.000	9	
Argentina	25.000.000	14.500.000	52	
Australia	50.300.000	9.000.000	18	
Paraguay	2.300.000	1.300.000	52	
Bolivia	1.900.000	417.000	22	
North India, Pakistan	191.700.000	561.000	<1	
South Africa	15.700.000	300.000	<3	
Uruguay	1.300.000	250.000	<5	
Venezuela	2.400.000	170.000	<5	
Chile	2.000.000	130.000	6	
Colombia	2.800.000	70.000	5	
Mexico	24.800.000	650.000	<5	
Ghana (100.000 farmers)	5.800.000	45.000	<1	
EU	73.500.000	430.000	<1	
Others		1.000.000		
Total	1.364.200.000	72.069.000	5,2	2003.

Source: Derpsch, R. 2003 vµ Dixon, J. M. 2003.

Early studies in soil mulching show clear effects of mulch in reduction of soil erosion and surface run-off (Lal, 1989) (Table 3, 4).

Table 3. Effect of soil mulch on run-off and soil erosion

Mulch amount (T/ha)	Surface run-off (%)	Soil loss (T/ha)	Source
0	50.0	4.83 100.00%	R.Lal, 1989
2	19.7	2.48 51.35%	With a rain of 61.1 mm
4	8.0	0.52 0.11%	Country: Nigeria
6	1.2	0.05 0.01%	

Table 4. Effects of mulch soil erosion and run-off

Yearly average	Control (Bare soil)	Mulch soil	% to control	Sources
Soil loss (T/ha)	232.6	0.2	0.09	R.Lal, 1989
Run-off (mm)	504.1	29.2	5.79	Slope: 10%
Run-off (%)	42.1	2.4	57.01	In Nigeria

It can be seen in tables 3 and 4 that the bigger the amount of mulch, the higher the soil erosion control capacity, and 6 ton of dry matter can completely stop the soil erosion.

In addition, mulch regulates the surface temperature of soil. So the mulch based technologies should be further studied, adapted and multiplied in many other countries.

Lessons learned from DMC research and development in Vietnam

Soil mulching is not new for Vietnamese farmers. Since long times, Vietnamese farmers used rice straw or crop residues to mulch their fields for increasing yield and quality of onion, garlic, root crops and vegetables in plat lands. Mulched crops developed better, their yield was higher, and their products had more beautiful appearance and could be sold with higher price.

However, farmers in mountainous regions are not familiar with such a technique, but they use to burn every vegetal material left on their fields before sowing. This is one of the most unwanted activities of slash-and-burn practices that we to fight to get rid of. Instead, we have to make most use of vegetal materials (crop residues, weed residues, material brought from other places or deliberately reduced on-the-spot (*in situ* mulch). S, since 1997, VASI and CIRAD started a research program named Agricultural Systems in Mountainous Regions of North Vietnam (or Systems Agraires des Montagnes du Nod Vietnam (SAM-SC) (Mountain Agrarian Systems) with mulch based direct sowing as the back born of all other techniques. The general research road map is to identify yield limiting factors and ways to overcome in a participatory, cost-effective and ecological manner.

Mulch materials:

- Crops' residues like rice straw, stems and leaves of maize, soybean, sugarcane leaves, and others;
- Stems and leaves of herbal species like weeds, Chromolaena, Tithonia, etc.;
- Wild and semi-wild legumes that have fast growth, high biomass and resistance to pests and diseases (Mucuna, Canavalia, Rice bean, Pueraria, etc);
- Biomass of high yield grasses like Brachiaria, Panicum, Paspalum, Pennisetum, etc.;
- Biomass of some cereals like millet, sorghum, job tears, barley, oats, ….;
- Other available sources.

Types of soils:

- Yellow, red feralits;
- Accumulative soils at the feet of limestone mountains;
- Sloping lands with different degradation levels and sloppiness.

Research methods-Due to great heterogeneity we have to use different experiment designs:

- Complete Block Design (CBD) or homogeneous fields;
- Augmented Design with control pairs;
- Multilocation tests in which a field, a household, or a location may be considered as a replication, and the normal fields are the control plots.

Research sites:

The main research sites are located in Cho Don district of Bac Kan (a Northern mountainous province). Then the obtained results were tested in other districts of the province (Bach Thong, Cho Moi, Ngan Son, Ba Be and Na Ri) by SAM Regional (a brother project supported by IRRI, IRD, and VASI. Besides, the Vietnamese Government supported Science and Technology Program for Mountain Agriculture and Rural Development lead by Dr Le Quoc Doanh – Deputy Director General of VASI, and Director of NOMARC, conducted a numerous tests of SAM in other districts of different mountainous provinces in the North like Cao Bang, Ha Giang, Son La, Lao Cai, Hoa Binh, etc…. SAM project also conducted joint activities with many other projects, particularly with EU Son La – Lai Chau Rural Development Project in order to scale up its innovations. In the line with this process, ICRAF has also supported with many mini-projects under Framework of ICRAF-VASI Cooperation. The main fields of these small grants are agro-forestry capacity building, knowledge sharing through different workshops, and scaling up agro-forestry innovations, many of them have been proposed by SAM project. At present, another Science and Technology Program for Mountain Agriculture and Rural Development in Tay Nguyen (Gia Lai, Contum, Dac Lak provinces). VASI has been invited to take part in this program, mainly to test and adapt conservation agriculture techniques developed by SAM in Bac Kan.

Reasons for soil degradation:

The root reason of soil degradation must be attributed to human production activities and mis-management of sloping lands, leading to severe soil erosion, making soil nutrients exhausted, yet the soil becomes acidic, toxic, compacted, losing water holding capacity, biological activity, etc. that means also losing productivity. As a consequence, the lands become bare, and the area of such bare lands and hills was increased fast in the 1980s. Conventionally, surface runoff is considered as the most important reason for soil degradation because it causes soil erosion. However, with the new look, it is the kinetic energy of raindrops that cause detachment of soil particles from the bare soil (Greenland, 1989) and then these particles are washed off by the runoff. So, the most important reason is the land cleaning, and the runoff is only the secondary reason. This way of argument makes us to think about the important role of soil cover in stopping soil erosion.

Reasons causing unstability of crop yield- Reasons for crop yield unstability are numerous, but the following are most important:

1. Land degradation, lack of nutrients, soil toxicity, compaction, low or no biological activity;
2. Lack of soil moisture because of low water holding capacity;
3. Infestation of pests and weeds.

Directions for soil erosion control:

SAM and our Mountain Program tried to use soil mulching methods to prevent the direct contact of the rain drops with the soil surface, mimicking the forest ecosystems mechanisms to improve the soil productivity. The projects paid high attention to biomass production, increase of the percentage and longevity of soil cover, promotion of soil biological activity and restoration of soil fertility (improvement of soil nutrients, organic matters, softness, biological activity, pH, etc. Base cations released from vegetal mulch can neutralize pH, and the humus micro-particles can absorb free aluminum and iron and reduce the soil toxicity. Once the porosity is high, the water holding capacity will increase and the surface run off will be reduced. That means the detachment of soil particles by the rain drops and surface run off (the two most important erosive factors) will be minimized. In other words, the soil erosion will be minimized.

Our study shows that soil mulch as the following benefits:

- Prevention of soil erosion,
- Increase of soil softness, water holding capacity,
- Reduction of evaporation or increase of soil moisture during dry times,
- Moderation of surface soil temperature,
- Increase in soil surface structure stability,
- Suppression of weeds, increase of fertilizers' effects,
- Increase in organic matters and other nutrients in the soil,
- Creation of favorable conditions for seed germination, better development of root systems and of course better plant growth and development.
- Decrease of input due to less labor for weeding, land preparation and less use of mineral fertilizers,
- Less dependence on weather when arranging sowing dates of second and third crops or inter-crops.

All the above effects lead to total increase in crop yield, quality and productivity, while preserving coil and water resources for their long-term use, contributing to forest development and environment protection.

It is necessary to notice that soil mulching should not be simply considered as taking vegetal materials to cover the soil. Soil mulching still includes different methods of producing more biomass, keeping soil mulched as much as possible. From this point of view, many common techniques like inter-cropping, relay cropping, etc. can be considered as soil covering techniques. Forests are also means of soil cover that is indirect cover. Planting fodder crops in young forests, fruit gardens and on bare

lands is also a measure of soil mulch. The following are the data obtained from our surveys in different localities.

Results and impacts of SAM project in Bac Kan province

Hundreds of experiments were conducted in Cho Don district of Bac an province in the North of Vietnam: dead mulch, living mulch, in-situ mulch, imported mulch, mini-terraces with soil mulch, soil cooking with subsequennt soil mulch, etc. Some important results are shown on tables 5 and 6.

Table 5. Effects of soil mulch on crop yield (SAM-1)

Crops	Yield (T/ha) No Mulch	Crops Yield (T/ha) Mulch	Increase rate (%)
Rice	0.96	1,92	100
	0.49	1.84	275
	0.42	1.08	163
Maize	3.12	4.01	28
	1.30	3.37	185
	1.50	2.50	67
Cassava*	18.6	26.9	44
	20.0	29.7	49
	16.5	24.0	45

* Living mulch by Stylosanthes guianensis.

Table 6. Increasing trend of maize yield intercropped with *Chucrasia tabularis* in mini-terraced field (VN, SAM 2002)

Field designation	Treatment	Yields (T/ha)		
		2001	2002	Increased by %
1002-1	Mini-terrace + Cassia rotundifolia	1.44	2.39	65.97
1002-2	Mini-terrace + A. pintoi	1.77	4.01	126.55
1003-1	Mini-terrace + B. ruziziensis (Cuttings from outside)	1.35	2.83	109.63
1003-3	Mini-terrace + B. riziziensis (seeded in 2000, killed in 2001)	1.59	2.11	32.70
1010-1	Mini-terrace + A. pintoi	1.18	4.17	253.39
1012-3	No mini-terrace + weeding	1.07		
1012-3	Mini-terrace + mulch in 2002		3.77	252.34

It can be seen that maize yield in mulched mini-terraces is not only much higher, but also increasing with time.

The effects of soil mulching on soil erosion control was studied by several authors (Table 7).

Table 7. Effects of miniterraces (MT) and soil mulch on soil erosion control

Treatment	Soil loss (t/ yr)	%	Locality	Source
Control	16.407	100.00	Na Ri	H.M.Tam
Miniterrace + No mulch	1.584	9.65	Na Ri	H.M.Tam
Miniterrace + Mulch	1.005	6.13	Na Ri	H.M.Tam
Plum + No mulch	12.7	100.00	Moc Chau	L.Q.Thanh
Plum + A. pintoi cover	3.500	27.56	Moc Chau	L.Q.Thanh
No miniterrace + No mulch	31.60	100.000	Na Ri	H.M.Tam
Miniterrace+mulch	0.24	0.76	Na Ri	H.M.Tam

It can be seen that the amounts of eroded soil are different, depending on mulch types and density, but erosion was minimized even to 6%. Some 30 communes in 20 districts and in 8 out of 12 Northern mountainous provinces have been selected for pilot application tests. The effects of soil mulching on increasing crop yields are shown on table 8.

Table 8. Effects of soil mulch on upland crops tested in other localities

	Yields (T/ha)			Location	Source	Note
	Control	Mulched	Increase by %			
Maize						
DK888	2.20	3.46	57.27	Na Ri	H.M.Tam	
LVN10	2.86	4.04	42.26	Na Ri	H.M.Tam	Miniterrace
CP	6.49	8.48	30.66	Mai Son	L.Q. Thanh	
LVN10	3.73	5.95	59.52	Song Ma	EU SLLC RDP and VASI, 2004	
LVN10	1.33	2.11	59.28	Song Ma	EU SLLC RDP and VASI, 2004	Miniterrace
LVN10	2.49	4.00	60.64	Tuan Giao	EU SLLC RDP and VASI, 2004	
LVN10	1.41	4.87	245.39	Tuan Giao	EU SLLC RDP and VASI, 2004	Terrace
LVN10	3.03	4.90	61.72	Dien Bien Dong	EU SLLC RDP and VASI, 2004	
LVN10	3.50	4.77	36.29	Dien Bien Dong	EU SLLC RDP and VASI, 2004	Terrace
LVN10	1.28	3.73	191.40	Phong Tho	EU SLLC RDP and VASI, 2004	
LVN10	3.48	6.75	93.97	Song Ma	EU SLLC RDP and VASI, 2004	
LVN10	4.00	6.48	62.00	Song Ma	EU SLLC RDP and VASI, 2004	Miniterrace
CP 888	4.75	7.75	63.16	Song Ma	EU SLLC RDP and VASI, 2004	
CP 888	4.78	7.00	46.44	Song Ma	EU SLLC RDP and VASI, 2004	Miniterrace
LVN10	1.58	2.10	32.91	Phong Tho	EU SLLC RDP and VASI, 2004	Terrace
Rice						
Dam Bao	1.25	2.25	80.00	Song Ma	EU SLLC RDP and VASI, 2004	
Dam Bao	1.55	2.14	38.06	Song Ma	EU SLLC RDP and VASI, 2004	Terrace
CIRAD 141	0.75	1.26	68.40	Song Ma	EU SLLC RDP and VASI, 2004	
Te Do	1.12	3.15	181.25		NOMARC, 2004	
CIRAD 141	1.80	3.20	77.78		NOMARC, 2004	
Average			79.42			

The yield increase is different due to very high level of heterogeneity in mountainous regions. However, the average increase is very high (79.42%). Such increase is not easy to achieve except high-tech methods that require enormous investment.

Another effect of soil mulching is regulation of soil moisture. Under the much, soil moisture is higher in dry season (Table 9).

Table 9. Soil moisture (L.Q.Thanh, VASI)

Treatment	Soil moisture (%) at different times					
	4/Nov.	19/Nov.	4/Nov.	19/Nov.	3/Jan.	18/Jan.
Plum + A.pintoi	33.64 *100%*	31.30 *100%*	29.50 *100%*	30.3 *100%*	33.62 *100%*	30.36 *100%*
Plum + no mulch	30.20 *89.8%*	27.32 *87.3%*	24.44 *82.8%*	24.6 *81.2%*	29.26 *87.0%*	25.54 *84.0%*
Maize + no mulch	29.90 *88.9%*	26.12 *83.5%*	24.12 *81.8%*	23.2 *76.6%*	28.24 *85.8%*	22.62 *74.5%*

It can be seen that at least the soil moisture in the mulched plots was 11% higher than the control, and the highest difference was 25.5%. As mentioned above, the soil animals play very important role in soil improvement. Their number and amount are very poor in degraded soils because of unfavorable for their development conditions. However, when the soils are properly mulched, the increased organic matters and moisture in the soil will stimulate soil biological activities. Earthworms decompose and circulate organic matters from the mulch. Some microorganisms take part in cellulose decomposition, others in phosphate solubilization and nitrogen fixation, etc. Besides, some other animals and microorgainsms play active role in creation of soil aggregates, porosity, aeration and water holding capacity, resulting in better growth and higher yields of crops. The data we received from experiments and surveys give an excellent prove for this (Table 10).

Table 10. Number of groups and species of earthworms and mesofauna under mulched fields in Na Ri (Bac Kan), Mai Son and Moc Chau (Son La)

Localities	Bac Kan		Son La									
	Na Ri		Mai Son						Moc Chau			
	Kim Lu		Chieng Mai		Co Noi				Sao Do State farm		Phieng Luong	
	Maize		Cassava		Maize		Suggarcane		Plums		Maize	
Groups of soil animals	C	Ex	C	Ex	C	Ex	C	Ex	C	Ex	C	Ex
Oligochaeta (Earthworms)												
Pheretima acalifornica		x										
Ph. abrevicapitata		x										
Ph. arrobusta		x										
Ph. arrobustoides											x	x
Ph. ampanoporophorata									x	x		
Ph. digna											x	
Ph. glabra											x	
Ph. hawayana									x			
Ph. hexita										x	x	x
Ph. morrisi				x					x	x		x
Ph. paraghilarovi										x		
Ph. robusta	x									x		
Ph. sucata										x		
Ph. thaibinhensis		x										
Ph. wui	x	x										
Dichogaster bolaui				x								
D. modigliani		x										
Pheretima	x	x		x	x	x	x	x		x	x	x
Total earthworm species	3	7		3	1	1	1	1	3	7	5	4
Total groups of soil animals	12	20	10	17	8	7	5	5	8	11	6	8

To compare the economic efficiency of mulch techniques, we calculated the input and the output of several treatments of soil mulch and those of the check plots (Control plots). The results are shown in table 11.

Table 11. Labor investment in the second season (Source: Nguyen Van Manh, NOMARC-EU SLLC RDP 2004, Song Ma)

Types of work	Terrace+Mulch	Terace+No mulch	No terrace + Mulch	No terrace + No mulch
Mulching soil	100 – 120	0	120 -130	0
Land preparation	20 – 30	80 -100	20 - 30	80-100
Weeding	(30 – 35)x2	(65 - 70)x3	(35 - 40)x2	(70 - 75)x3
Total	180 - 220 (200)	275 – 310 (292.5)	210 – 240 (225)	290 – 325 (307,5)
Balance (%)	*68%*	*100%*	*73%*	*100%*

The data on table 11 show that it takes about 100 days to mulch the fields, but it can save 60 to 70 days for land preparation, and 80 to 100 days for weeding. In total, this can save 35 to 40% as compared to farmers' practices.

Table 12. Economic analysis of soil mulch (case study of local rice variety Dam Bao) (Source: Nguyen Van Manh, NOMARC-EU SLLC RDP 2004, Chieng So-Song Ma)

Treatment	Terrace + Soil mulch	Terrace + No mulch	No terrace + Mulch	No terrace + No mulch
NS kg/ha	2156	1550	2250	1250
Total harvest value (VND/ha)	5.390.000	3.875.000	5.625.000	3.125.000
Total labor/ha (VND/ha)	3.000.000	4.387.500	3.375.000	4.612.500
Benefit (VND/ha)	2.390.000	-512.500	2.250.000	-1.487.500

Note: Expenses for seeds, fertilizers, harvest, drying are supposed to be equal.

It can be seen from table 12 that due to low yield in unmulched fields, the total harvest value cannot cover the expenses. So, they have to clean some parts of forests to open new fields for food crop cultivation. In contrast, soil mulch resulted in much higher yield, so they get more than 2 million VND/ha.

Table 13. Economic analysis of soil mulch (case study of maize variety LVN10 in Chieng So-Song Ma) (Source: Nguyen Van Manh, NOMARC-EU SLLC RDP 2004)

KT/NSkg/ha	Mulch	No mulch	Miniterrace + mulch	No miniterrace + No mulch
Yield (T/ha)	6.750	3.470	6.475	4.000
Mineral fertilizers (1000 VND/ha)	915	915	915	915
Labor (1000 VND/ha)	3.300	3.600	3.900	2.570
Revenue (kg/ha x2500 VND/kg) (1000 VND/ha)	12.150	6.246	11.655	7.200
Balance (1000 VND/ha)	7.835	1.731	7.740	4.715
%	453	100	164	100

Table 14. Economic analysis of soil mulch (case study of maize variety LVN10 on miniterrace in Na Ri-Bac Kan) (Source: H.M.Tam, VASI, 2004)

Treatment	Yield (T/ha)	Total harvest value (1000VND/ha)	Total Expenses (1000VND/ha)	Benefit (1000VND/ha)	%
No miniterrace + no mulch	5.61	10.098	3.085	7.013	100
Miniterrace + no mulch	6.73	12.114	3.885	8.259	117.77
Miniterrace + mulch	9.08	16.344	5.085	11.259	160.54

Table 145. Economic analysis of soil mulch (case study of maize variety LVN10 in Van Chan – Yen Bai) (Source: V.T.Luu, NOMARC, 2004)

Commune	Treatment	Yield (T/ha)	Harvest value (1000 VND/ha)	Expenses (1000 VND/ha)	Benefit (1000 VND/ha)	%
Suoi Giang	No mulch	2.44	5490	2890	2600	100
	Mulch	3.06	13700	5700	8000	308
Suoi Bu	No mulch	2.85	6400	2890	3510	100
	Mulch	3.23	14500	5770	8730	249

From tables 12, 13,14 and 15, it can be seen that economic efficiency is always higher in mulched plots than in control ones. However, the level of change varies from 20 to several hundreds percents.

III. Conclusions and proposals

Conclusions:

Vietnamese agriculture has achieve tremendous results in the last decades, but negative impacts of conventional agriculture have been exposed like decline in soil properties, yield limit and decrease, soil degradation, environment degradation, increased natural calamities, etc. These forced to seek alternatives to conventional agriculture. For the irrigated lowlands of Vietnam, crop diversification, conversion of unproductive to more and high productive production patterns, use of hybrid F1 seeds, increase crop seasons by using short duration varieties, relay cropping, etc. proved to be effective measures to increase land and labor productivity. In the uplands, however, there are many constraints in very fragile agro-ecological conditions. So, we have to use very careful and comprehensive approaches if sustainability is the main target. From the studies within the KASSA project on the impacts of some projects like SAM (Mountain Agrarian Systems) project and other research and development programs conducted in mountainous areas of North Vietnam, we found that:

- Soil mulching is a cost effective and universal method. It helps us solve soil constraints in more sustainable ways. The most important role of the mulch is the complete stop of soil erosion that also means the stop of soil degradation. This helps farmers in setting permanent fields for food production with high and stable yield. With time, the vegetal mulch will decompose releasing necessary nutrients for plant growth and give high yields. Due to high heterogeneity in soil conditions, the yield increase varies widely from 20% to several hundreds percents with the average of 79.4%. So, farmers can reduce their labor because they can reduce cultivated areas and

can get higher production. The lands freed from food production can be used for other high cash value crops or for planting fruit trees and forest species.

- Some people may claim that more labor is required when applying DMC. This may be true at the first season when much had not been prepared. However, this can be compensated by reduced labor in weeding and lad preparation. In the long run, among with increasing economic efficiency, DMC will bring about multifaceted benefits.
- Soil much stimulates biological activities in the soil, softening its texture, improving porosity and water holding capacity. Among soil fauna and flora, earth worms play vary important role in improvement of soil fertility. There are useful organisms like nitrogen fixing, phosphate solubilizing and cellulose decomposing organisms. Some fungi can protect the soil from being compacted by formation of micro-aggregates. As a result, the soil becomes very soft, and there is no need for plowing.
- With proper amount (7 to 10 tones of dry matter/ha), mulch may completely suppress the weed growth, reducing much labor for weeding. Women are released from hard work in the fields, so they have more time to take care of their children and families or to do handy craft or other off-farm activities.
- Once, the water holding capacity is increased, the soil absorbs more water making it available to plants for longer time. In addition, this can greatly reduce the surface run-off that also reduces its erosive effect. The reduced soil erosion in turn will reduce the siltation of rivers and water reservoirs. This will save a lot of expenses for cleaning and maintaining these engineerings.
- With time, the soil fertility will be much improved and the requirement for mineral fertilizers will be minimized. So, a large amount of energy that is supposed to be used to produce fertilizers will be saved and less green house gasses will be released, contributing to natural resources preservation and environment protection.
- So, Soil mulch and direct sowing with minimum soil tillage, together with other sustainable sloping land agricultural technologies, will provide basic foundation for sustainable agricultural development in upland regions, not only in Vietnam but in any locality where sloping land agriculture exists.

Proposals

Knowledge and experience of mulch based direct sowing technologies should be shared among countries in the world. But to scaling up these innovations, closer international cooperation should be developed, in which poor countries should be supported. Regional conservation agriculture networks could be developed regional cooperation in further research and development of sustainable agriculture, especially in mountainous regions.

Appendixes

Population increase in some localities in North Vietnam (Person/km^2)

Year / Locality	1962	1964	1990	1999	2000	Average increase Person/ha/year
North West			52		64	1,2
North East			118		137	1,9
Hoa Binh province					165	
Ban Cuon – Ngoc Phai - Cho Don –Bac Kan	11	22		47		1,0
Ban Dieu - Ngoc Phai - Cho Don –Bac Kan	08	13		31		0,6
Average annual increase (Person/ha/year)						1,18

(Source: Chu Huu Quy, 2002; SAM-SC, 2002)

Rice production in Northern mountainous regions of Vietnam

Year / Region	1990			2003			Annual increase rate (%/Annum)		
	Area (1000 ha)	Yield (T/ha)	Production (1000 tons)	Area (1000 ha)	Yield (T/ha)	Production (1000 tons)	Area	Yield	Production
Northeast	522.3	2.86	1494.0	565.5	4.36	2465.6	0.6	6.5	5.0
Northwest	134.5	2.45	329.5	139.3	3.47	483.4	0.27	3.2	3.6
Whole country	6042.8	3.18	19225.2	7449.3	4.62	34447.5	1.8	3.5	6.1

Situation of forest lands in Vietnam in 2002 (1000 ha)

Classification	Total area	Percentage (%)
Total natural land area	32929.0	100
Forest lands with forests	12051.2	36.5
Natural forests	9889.6	30.3
• Production forests	3597.8	10.9
• Protection forests	4883.4	14.8
• Special use forests	1508.4	4.6
Planted forests	2036.8	6.2
• Production forests	1360.9	4.1
• Protection forests	610.2	1.9
• Special use forests	65.7	0.2

Source: Adapted from Statistical Year Book 2003)

Area of bare lands and hills over time

Year	Area of bare lands and hills (1000 ha)	Percentage to total natural area (%)
2003	8,390.5	25.50
1999	10,027	30.5
1995	11,638	35.3
1990	11,768	35.7
1985	11,051	33.6
1980	10,035	30.5
1976	9,774	29.6
1943	6,643	20.0

(Source: MARD 2001, 2003, after Vu Tien Hinh, 2003).

Per capita cereal food and forest coverage in Northern mountainous provinces

	1990	2000	2003	Forest coverage (%)
Northeast	202.5	278.5	327.4	41.28
Ha Giang	231.3	313.2	360.1	38.96
Cao Bang	301.9	329.9	371.0	38.16
Lao Cai	200.3	249.2	303.8	37.51
Bac Kan	218.7	312.4	390.8	50.96
Lang Son	221.0	266.0	334.1	38.87
Tuyen Quang	248.1	326.2	422.6	56.51
Yen Bai	200.0	246.1	272.4	43.15
Thai Nguyen	188.6	281.0	330.2	43.01
Phu Tho	171.2	254.8	316.8	42.30
Bac Giang	210.8	332.5	358.8	28.18
Quang Ninh	130.3	185.9	215.8	38.05
Northwest	2605.8	277.2	342.5	37.34
Lai Chau	244.4	289.3	332.5	39.58
Son La	178.6	269.2	341.2	34.19
Hoa Binh	207.8	277.0	352.0	38.69

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