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PAPER REVIEWS

AGRO-ENVIRONMENTAL LESSONS FROM THE 'SUSTAINABLE HIGHLAND AGRICULTURE IN SOUTH-EAST ASIA' (SHASEA) PROJECT

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Abstract. To promote sustainable agro-environmental development in the highlands of South-East Asia, an international multidisciplinary research team examined the effectiveness of selected agronomic and soil conservation treatments (both modified and novel cropping practises) using farmer-managed runoff plots. The study sites were located in the highlands of Yunnan Province (Wang Jia Catchment), China and Mae Honson Province (Pang Mapa District), Northern Thailand. Project lessons relating to co-operation, research partnerships, time horizons, multidisciplinarity, income generation, information dissemination and education are discussed.

Keywords: China, north-south co-operation, soil conservation, INCOPLAST, south-south co-operation, straw mulch, alley cropping, sustainability, Thailand, time-horizons.

1. Introduction

Demands for increased food production, coupled with rapid industrialization and urbanization, have placed considerable pressure on land use and agro-environmental systems in the highlands of South China and South-East Asia. Shifting cultivation (swiddening), agricultural intensification and greater use of these fragile sloping areas are causing serious soil erosion, leading to severely decreased soil productivity and agro-ecological, environmental quality, catchment function and socio-economic problems. Soil erosion is causing particularly serious long-term agricultural sustainability problems. For instance, crop yields on sloping land in southern China and northern Thailand are notably decreasing due to soil erosion and, it is estimated, within 50–100 years most topsoil will have been removed (Fullen *et al*. 1997, 1999). Furthermore, siltation and sedimentation from water erosion decreases both river depths and reservoir holding capacities, leading to flood and drought problems during the wet and dry seasons, respectively. More effective soil conservation is, therefore, essential for sustainable crop productivity and environmental protection on these hill slopes.

To date, China has one of the world's most severe soil erosion problems (Higgitt 2000; Fullen 2004; Fullen *et al.* 2000, 2004; Watts and Zhou 2000). Total erosion is estimated at 5500 million tonnes of soil per year, with associated loss of 27.5 million tonnes of organic matter (Wen 1993). Vlassak *et al.* (1993) reported that median soil losses in northern Thailand varied from 5–297 t ha^{-1} y^{-1} under median rainfall totals of 1132–1723 mm y^{-1}, depending on rainfall characteristics, slope gradient and cropping practises. Erosion is one of the main factors limiting and decreasing soil productivity on sloping land. Water erosion removes topsoil, reduces available water holding capacity and soil structural stability, causes surface sealing and reduces soil infiltrability (Rhoton and Tyler 1990). It is estimated that Chinese annual soil and nutrient loss accounts for $18–30 \times 10^9$ kg of food loss per year (Xu 1995). Given the land resource pressures exerted by the vast population, this highlights the need to increase food security through the development of appropriate new technologies or cropping practises that are sustainable, available and economically affordable to rural communities.

Based on these issues and concerns, the 'Sustainable Highland Agriculture in South-East Asia' (SHASEA) Project was implemented with an integrated and holistic approach to increase the productivity and sustainability of cropping systems in the highlands of South-East Asia: (http://134.220.18.206/cs1965/shasea/consasia.htm) (accessed 18/06/2010).

The Project involved the participation of scientists from many diverse disciplines (agriculture, biology, eco-

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nomics, geology, hydrology and soil science), from different West European and Asian countries, working alongside local farmers and their families in South China and South-East Asia.

Particular attention focused on conservation treatments and cultivation effects on crop productivity and soil erosion rates on subtropical arable red soils of the Upper Yangtze basin in the Central Plateau of Yunnan Province, China. Within this context, this paper describes the progression and research findings of the Project phases and work-packages and details specific project design and management lessons gained from the SHASEA Project. These lessons can be employed by similar research projects that promote sustainable agro-environmental development in tropical and subtropical highlands.

2. The Sustainable Highland Agriculture in South-East Asia (SHASEA) Project

A project team was assembled to provide multidisciplinary analyses of the complex agro-environmental problems. The SHASEA team consists of scientists from Belgium, China, Ireland and Thailand, co-ordinated by a U.K. partner. Plot studies have been used to develop and test novel cropping techniques. This on-going programme has established experience-sharing links with the local community (farmers, villagers and township officials), which was crucial for incorporating *'end users'* in the research programme and for promoting *'bottom-up'* development. The participative research strategy, sharing experience between European and Asian partners, facilitated a holistic approach, which was essential to long-term programme success. The Project aimed to disseminate information to international research communities, regional training agencies, local agricultural and conservation services and village communities. The team believes the interchange of research information between China and Thailand will be beneficial for sustainable development in the highlands of South-East Asia (Fig. 1).

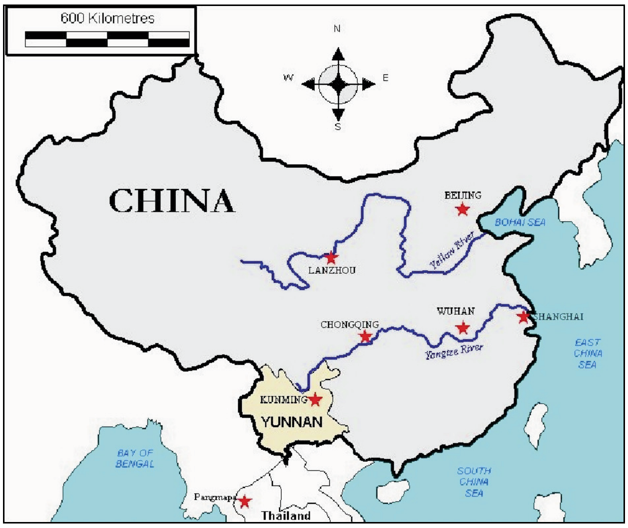

Fig. 1. Map of South-East Asia showing the studied sites in South China and Northern Thailand

Five co-ordinated work-packages were implemented: (1) background agricultural and environmental assessment of the highland catchment; (2) implementation and evaluation of modified and novel cropping systems for wheat, maize and soybeans in the catchment; (3) evaluation of the socio-economic impact of changed cropping practises; (4) comparative scientific evaluation of the soil and water conservation techniques used in association with maize and lablab bean (*Lablab purpureus*) production in the highlands of northern Thailand and (5) dissemination of project outcomes and establishment of training programmes for best practise in highland rural development. However, due to the magnitude of the collated data and information, not all these work-packages are discussed in detail within this paper.

2.1. Phase 1: An Integrated Study of Wang Jia Catchment

To contribute to the development of appropriate soil conservation strategies, a runoff plot study at Yunnan Agricultural University, Yunnan Province, China (25°08'N, 102°45'E; elevation 1930 m) evaluated the effectiveness of various soil conservation measures (Fig. 2). A programme has been maintained for each cropping season since 1993. Several cropping treatments were applied to maize. Maize was grown on 30 erosion plots built on three slope classes (Classes I-III), with 10 plots in each and with mean slope angles of 3, 10 and 27° (5, 18, 51%), respectively. The plots in Classes I and II measured 24 m^2 (8×3 m), while those in Class III measured 7.2 m^2 (6×1.2 m), these being smaller because of space limitations.

Throughout each season, measurements were taken of runoff and erosion rates, crop yield and yield components, plus soil thermal and hydrological regimes. Results strongly suggest the benefits of straw mulch and contour

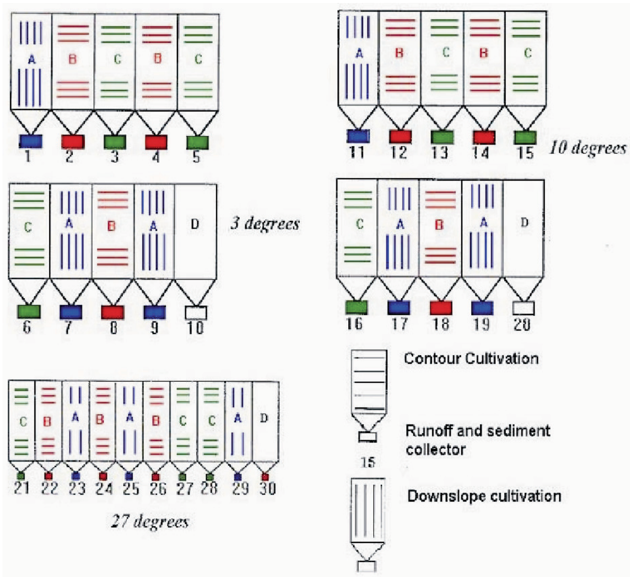

Fig. 2. Sketch plan of the runoff plot study at Yunnan Agricultural University, Yunnan Province, China (25°08'N, 102°45'E; elevation 1930 m). (A) downslope cultivation; (B) contour cultivation; (C) contour cultivation plus straw mulch; and (D) bare soil

cultivation in conserving soil, water and nutrients (Fullen *et al*. 1997, 1999; Barton 2000; Barton *et al*. 2004; An Tongxin 2002). During the rainy monsoon season (May to October), runoff and erosion rates were measured on a storm-by-storm basis. Table 1 summarizes erosion rates from 1993–96 and illustrates the effectiveness of both straw mulch and contour cultivation.

From 1997–2000 the plot design was modified, replicating the most effective treatments of straw mulch and contour cultivation, with conventional tillage as the control. To quantify potential erosion rates, there were three bare plots, one on each slope class. Data from the 1997–1999 seasons confirm that straw mulch and contour cultivation significantly decreased soil erosion rates. Table 2 shows representative data from 1998, which suggests a possible additive interaction between contour cultivation and straw mulch, which increases in effectiveness on steeper slopes (Zhao Yan 1999; Milne 2001; Milne *et al*. 2002, 2004).

The team recognized further progress required full evaluation of the applicability of techniques developed in plot studies in actual field conditions. This was achieved by the development and scientific evaluation of modified and novel cropping practises in a representative highland catchment in north-east Yunnan (~60 km north-east of Kunming). The selected catchment, Wang Jia (25°28'N, 102°53'E) near Kedu, in Xundian County, serves as a teaching, research and extension facility (Fig. 1). The 40.1 hectare catchment has an altitude of 2044–2191 m and includes sloping cultivated land (27.3 ha), sweet chestnut trees (1.1 ha), rocky land (0.4 ha), forest trees (9.5 ha) and unproductive hill land (1.8 ha). Phase 1 of the Wang Jia Project evaluated the effects of modified cropping practises on maize productivity and soil properties. In 1998, 15 plots were established in a randomized block design. Plots were 30 m^2 (3 × 10 m), on slopes ranging between 13–19° (23–34%) and they received five treatments, each with three replicates planted with maize. Treatments were: traditional cultivation + down-slope planting (T+D); traditional cultivation + contour planting (T+C); traditional cultivation + contour cultivation + straw mulch (T+C+St); minimum tillage + contour cultivation + straw mulch (M+C+St) and traditional cultivation + contour cultivation + polythene mulch (T+C+P). Results in 1998 and 1999 highlighted significantly greater maize productivity from plots covered with plastic mulch (Table 3). This effect was attributed to relatively higher measured soil temperatures (≤4 °C) and soil moisture contents (~2% by weight) beneath the plastic mulch (Huang Bizhi 2001; Huang Bizhi *et al.* 2002).

2.2. Phase 2: The Wang Jia Catchment Study

Phase 1 of the Project provided invaluable preparatory data for Phase 2. It was imperative that the full socio-economic implications of changed cropping strategies were assessed. Preliminary cost-benefit analysis of plot data suggested increased crop yields could increase farm incomes by ~10% per year ($180 per hectare) and thus provide a considerable stimulus to the rural economy. However, there is a strong need to evaluate the effectiveness of any intended soil conservation strategy within an

Table 1. Influence of cropping direction, slope and surface treatment on mean erosion rates (Mg ha^{-1}, t ha^{-1}) during 1993–96 (source: Barton 2000)

Slope/ cropping direction	Conventional Tillage	No-tillage	Straw mulch	Polythene mulch	Inter-cropping	Mean
Slope I						
Contour	0.96	0.68	0.44	0.76	0.68	0.70
Downslope	0.70	0.78	0.47	2.26	0.98	1.04
Mean	0.83	0.73	0.46	1.51	0.83	0.87
Slope II						
Contour	3.95	3.32	0.94	2.45	1.37	2.41
Downslope	4.39	2.75	0.86	4.72	4.47	3.44
Mean	4.17	3.04	0.90	3.59	2.92	2.92
Slope III						
Contour	4.30	5.94	1.22	7.15	3.77	4.48
Downslope	10.69	6.26	1.51	7.59	6.19	6.45
Mean	7.50	6.10	1.37	7.37	4.98	5.46

Table 2. Mean soil loss (Mg ha^{-1}) for the 1998 cropping season (source: Milne 2001)

Treatment	Slope I (3 degrees)	Slope II (10 degrees)	Slope III (27 degrees)
Downslope	3.07 ± 0.98	19.11 ± 3.30	6.92 ± 0.81
Contour	0.58 ± 0.19	8.00 ± 3.16	6.28 ± 2.11
Contour + straw mulch	0.21 ± 0.12	3.51 ± 2.74	0.04 ± 0.05
Bare	21.18	79.11	43.4

Notes:

Cropping season 21 May–7 October 1998.

Precipitation amount 1024 mm.

Mean soil loss refers to mean of three replicate plots ± standard error of the mean, excluding the bare unreplicated plot.

Table 3. Effects of cultivation techniques on grain yield (Mg ha^{-1}) from the experimental plots at Wang Jia in 1998 and 1999 (source: Huang Bizhi 2001)

Year	Blocks	Treatments				
		T+D	T+C	T+C+St	M+C+St	T+C+P
1998	A	4.4	5.6	4.7	5.2	5.8
	B	4.0	5.2	5.0	4.6	5.4
	C	4.6	5.4	5.2	5.0	5.8
	Mean	4.3a	5.4bc	5.0b	4.9b	5.7c
		n = 3,	F = 11.32,	P<0.001,	$LSD_{(0.05)}$ =	0.41 t
1999	A	6.4	7.6	7.5	6.2	9.2
	B	5.8	6.7	7.2	6.0	9.5
	C	5.7	7.2	7.3	6.1	8.6
	Mean	6.0a	7.2b	7.3b	6.1a	9.1c
		n = 3,	F = 40.28,	P<0.001,	$LSD_{(0.05)}$ =	0.50 t

Notes: Grain yield measured using air-dried cobs harvested from whole plots. Values converted to Mg ha^{-1} at 13% moisture content and analysed by ANOVA, with significant differences ($P < 0.05$) denoted by different letters. Treatments were: traditional cultivation + downslope planting (T+D); traditional cultivation + contour planting (T+C); traditional cultivation + contour cultivation + straw mulch (T+C+St); minimum tillage + contour cultivation + straw mulch (M+C+St) and traditional cultivation + contour cultivation + polythene mulch (T+C+P).

a) general view of Wang Jia Catchment from near the summit

b) shows the mid-section of Wang Jia Catchment

Fig. 3. Wang Jia Catchment (25°28'N, 102°53'E) near Kedu, in Xundian County, serves as a teaching, research and extension facility

appropriate socio-economic context. Therefore, Phase 2 aimed to increase the productivity of wheat, maize and soybean grown on hill slopes using sustainable and environmentally-friendly farming practises. The twin goals of increased productivity and sustainability were achieved by the development and scientific evaluation of modified and novel cropping practises. Full environmental and socio-economic assessments of these developments were also carried out, covering physical, chemical and ecological impacts, the conservation of natural resources, levels of inputs and losses, waste management, stakeholder returns, poverty alleviation, income augmentation and rural development. Today, the catchment continues to be used as an experimental area, but also acts as a training model for sustainable agricultural development in the South China highlands (Fig. 3).

2.3. Work-package 1: Agricultural and Environmental Assessment of Wang Jia Catchment

This work-package, co-ordinated by Gembloux Agricultural University (Belgium), focused on catchment geomorphopedology. This involved the installation of a research support infrastructure that included an integrated irrigation system, catchment flume, upgraded access road, Delta-T Weather Station and gully check dams. In consultation with local farmers, a land management plan was designed and implemented. This included afforestation of upper areas with pine *Pinus armandii* (24,150 seedlings), prickly ash *Zanthoxylum bungeanum* (4,076 seedlings) and sweet chestnut *Castanea mollissima* (11,037 seedlings) trees, which were transplanted into forest gaps in August 2000. Arable cultivation was concentrated on the gentler slopes of the mid-catchment. Irrigation facilitated a good wheat crop during the dry winter season and assisted early spring growth of maize, thus encouraging the rapid development of crop cover to protect soils from erosive monsoon rains.

The main results achieved included improvements to the existing topographic map, which is a digitized catchment map that is geo-referenced in the UTM projection system (Fig. 4). This is the base document for all thematic maps produced, such as the land use and plantation maps. Comparing geomorphological and land use characteristics with those of the whole mountainside, south of Kelang village, enabled the evaluation of the representativeness of Wang Jia Catchment. Comparison between hypsometric curves, slope classes and SPOT satellite image interpretation (coloured image composition, image classification, vegetation index) showed Wang Jia to be representative of the Kelang mountainous area.

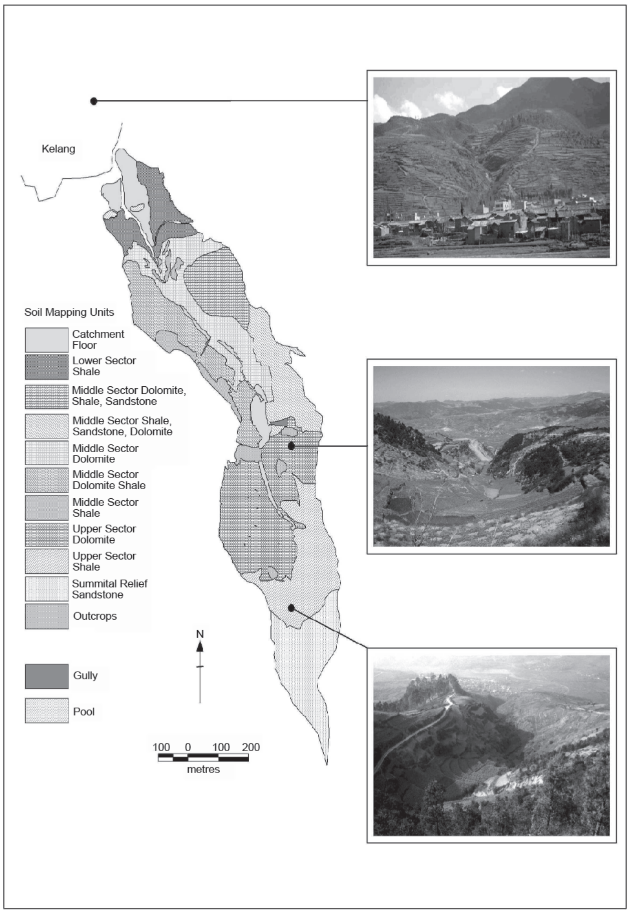

Fig. 4. Soil mapping units of Wang Jia Catchment. The digitized catchment map is geo-referenced in the UTM projection system (Source: Gembloux Agricultural University)

A detailed catchment land use map was built up from observations gathered from field surveys and aerial photographs. Lithological and geomorphological surveys were also carried out, to include catchment geology and geomorphology data. This included an erosion assessment and an investigation of soil physical properties, especially water availability for plants. Soil identification and soil fertility evaluation allowed a synthesis in the form of a catchment geomorphopedological sketch map, with associated table legend. Reference plots ensured a link with socio-economic data gained at farm level in Work-package 3.

A digitized 1:50,000 topographic map was prepared (year 2000) and new field observations led to improved map accuracy. A land cover map was prepared using a multispectral SPOT 4 image. Base maps were also used to produce additional maps showing plant water availability, potential runoff and erosion features. A quantitative evaluation of the effectiveness of soil conservation practises was conducted on three representative lateral transects, covering the 1930 m catchment length. The study shows that, due to erosion on convex and steep linear slopes and, subsequent accumulation in concave positions, soils are notably young and demonstrate strong evidence of rock heritage. This is indicated by the dominant illite/chlorite clay mineral assemblage, a silty texture and the yellowish brown soil colour, on slopes where sandstone and shale outcrop. From upstream to downstream and from top- to down- slope, colluvial-mixing increases, textures become finer, soil colour darkens (except in the catchment outlet) and soil pH increases. This has a direct impact on relatively high soil potentialities; plot fertility ranging from dystric (low fertility status) to eutric (high fertility status).

Mineralogical analyses of Wang Jia soils identified three main lithological influences, namely shale, sandstone and dolomitic limestone/dolomite (dolostone). Shales outcrop in northern and eastern parts of the catchment and are locally interbedded with dolomitic limestones and sandstones in the mid-catchment. Sandstones outcrop mainly in the southern and uppermost part of the catchment. Fifty-four soil samples, representing 19 soil profiles from the catchment and associated landscape units were analysed for pH (H_2O and $CaCl_2$), exchangeable H, Al, Mn and Fe, exchangeable bases (Ca, Na, K and Mg), total C, total N and mineral magnetic properties. From these data, soil cation exchange capacity (CEC), % base-saturation, % H+ saturation and C/N ratios were calculated. In many parts of the catchment, soil pH was relatively high, often approaching or even exceeding 7, and had full base-saturation. The most acidic soils were mainly in the upper catchment. Six benchmark soil profiles were also sampled from various catchment landscape units. Profiles 1 and 2 were sampled from the upper catchment. These soils have yellowish brown colours and were acidic towards the surface (pH <5.5, base-saturation <50%) and were classed as Inceptisols (Dystropepts). From mineralogical data, it was concluded they showed little evidence of intensive weathering. Profiles 3, 4 and 5, from the intermediate catchment sector, were more reddish and, depending on the nature of the parent material, had higher pH and base-saturation levels. Profile 6, in the lower catchment, near the outlet and Kelang village, had yellowish brown to yellowish orange soil, pH always >7, fully base-saturated throughout and a clay mineralogy identical to Profiles 4 and 5.

A land information system was developed for Wang Jia Catchment. Information, including meteorology, geology, geomorphology, biology, pedology and crop productivity, was integrated using a geomorphopedological approach and expressed as maps using GIS, especially LandIS software (Li Yong Mei 2004). The land information system is considered suitable for designing, evaluating and monitoring sustainable agricultural practises central to soil conservation and crop yield improvement and thus contributing to decision-making for sustainable agricultural land management in this region. The developed protocol is proposed as a generic system, applicable to agricultural land evaluation in subtropical highland catchments (Li Yong Mei 2004).

2.4. Work-package 2: Implementation and evaluation of modified and novel cropping systems

This work-package, co-ordinated by Yunnan Agricultural University, included several field experiments using maize and soybean crops. These involved: (i) investigation of different cultivation techniques, including use of contour cultivation, straw mulch, vetiver grass, minimum tillage, plastic mulch and a novel combination of mulching techniques and intercropping; (ii) evaluation of alternative cropping strategies, including the use of different cash crops and perennial crops, fallow areas and different rotations, leading to the development of a catchment management plan for improved productivities, increased economic return and improved sustainability (Wang Shu Hui 2003; Li Yong Mei 2004; Li Yong Mei *et al*. 2005); (iii) implementation of improved water conservation and irrigation management systems; (iv) implementation of engineering measures to reduce flooding and (v) planting of trees (pine, sweet chestnut and prickly ash) and grass strips on steeper slopes for soil stabilization.

Based on field and plot experience, the team designed a composite maize cropping system to maximize both crop yield and soil/water conservation, known as the 'Integrated Contour Cultivation, Plastic and Straw Mulch Treatment' (INCOPLAST), which combines contour cultivation, straw mulch and plastic mulch. To establish early crop growth and to maximize yield, irrigation water is applied prior to monsoon rains. The INCOPLAST system is then installed, to both maximize yield (by addition of plastic mulch) and conserve soil, water and associated nutrients (by installation of contour cultivation and straw mulch) (Fig. 5). Ridge morphology is shaped to route water towards the maize roots beneath the plastic mulch. Experiments proved soil bulk densities beneath the plastic mulch remained low throughout the growing season, thus promoting easier root penetration, higher aeration porosity, higher infiltration and lower runoff rates (Huang Bizhi 2001; Huang Bizhi *et al*. 2002).

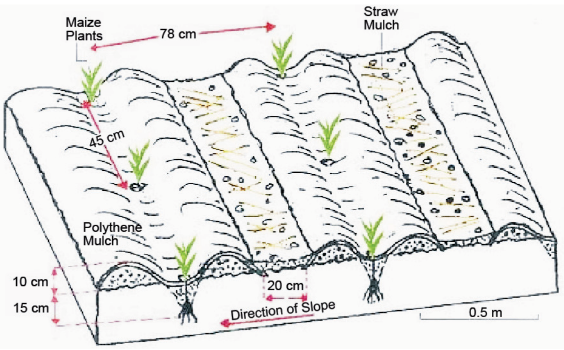

Fig. 5. Sketch of the INCOPLAST technique

The INCOPLAST technique was first installed at Wang Jia in 1999 and resulted in significant ($p < 0.05$; $n = 3$ plots) increases in grain yields of 48.7% compared with the downslope control (Wang Shu Hui 2003). Positive results encouraged its adoption by local farmers. Crop yield increases are comparable to the significant improvement produced by plastic mulch. However, INCOPLAST may offer the added advantages of improved soil, moisture and nutrient conservation and it is believed these benefits will be particularly apparent during erosive and/or drought periods. The INCOPLAST technique was repeated during 2001 and 2002 cropping seasons and applied to the Kunming runoff plots during the 2000 and 2001 cropping seasons (An Tongxin 2002). To enhance soil, water and nutrient retention within fields, experimental plots were bordered with grasses, including vetiver grass (*Vetiveria zizanoides*). Evaluation of grass performance is still in progress, but it is noteworthy that it is near its climatic tolerance limits, so results will prove valuable for agro-environmental management in the South China uplands.

Five maize cropping practises were evaluated using plot studies (Table 4). These were: (i) traditional cultivation with downslope planting (D); (ii) traditional cultivation with contour planting (C); (iii) traditional cultivation with double ridge contour planting and polythene mulch (C+P); (iv) traditional cultivation with double ridge contour planting, polythene mulch and straw mulch (C+P+S) (i.e. the INCOPLAST treatment) and (v) traditional cultivation with contour planting, polythene mulch and intercropping with soybean (C+P+IS).

Table 4. Effects of treatment on maize crop yield (mean of three years 1999–2001) (source: Wang Shu Hui 2003)

Treatment	D	C	C+P	C+P+S	C+P+IS
Yield ($Mg\ ha^{-1}$)	7.0	7.8	9.6	9.6	9.3
% increase	–	11.4	43.3	43.3	38.8

Notes: traditional cultivation with downslope planting (D); traditional cultivation with contour planting (C); traditional cultivation with double ridge contour planting and polythene mulch (C+P); traditional cultivation with double ridge contour planting, polythene mulch and straw mulch (i.e. the INCOPLAST treatment) (C+P+S) and traditional cultivation with contour planting, polythene mulch and intercropping with soybean (C+P+IS).

The main conclusions from these plot studies are: (i) control treatment (D) produced maize cob yields in the range 4–7 $Mg\ ha^{-1}$, with a mean (three cropping seasons 1999–2001, three replicate plots) of 6.7 $Mg\ ha^{-1}$, which is above the average maize yield for Yunnan Province of 3.9 $Mg\ ha^{-1}$; (ii) contour treatment (C) produced yields in the range 5–8 $Mg\ ha^{-1}$, with a mean of 7.6 $Mg\ ha^{-1}$. In most experiments, the mean value was not significantly different from treatment D; (iii) polythene treatment (C+P) produced yields in the range 8–12 $Mg\ ha^{-1}$, with a mean of 9.6 $Mg\ ha^{-1}$. These yields were no greater than those obtained in a separate experiment for a single ridge system; (iv) addition of straw mulch between the ridges and the use of a double ridge (INCOPLAST, C+P+S) compared to a single ridge, as used in a separate experiment, produced no significant additional increases in yield over C+P; (v) intercropping with soybean (C+P+IS) produced yields in the range 8–10 Mg ha^{-1}, with a mean of 9.3 Mg ha^{-1}, which was not significantly different to either treatment C+P or C+P+S; (vi) highest yield, in a separate experiment using a single ridge, for C+P was 10.2 Mg ha^{-1}. Results from two seasons of winter wheat studies, with wheat grown in the season between maize crops, showed notable yields were achieved for both wheat grain and straw. Furthermore, this proved to be very valuable for summer straw mulching needs. However, other results demonstrated previous crop treatments had no significant influence on crop properties. Physical measurements suggest increased crop response may be partly due to higher soil temperatures and improved soil moisture retention in the early season. Pre-irrigation, in advance of the onset of the rainy season, followed by mulching treatment, is particularly beneficial. This enables rapid crop development and thus high crop yields. Furthermore, rapid vegetative cover development, especially maize canopy closure, is highly beneficial for resource (soil, water and nutrient) conservation. In a separate experiment, using the Kunming erosion plots, the C+P+S treatment was the most effective for soil and water conservation, yielding least runoff and soil loss (An Tongxin 2002); (vii) in terms of increasing maize productivity, the most effective treatments were C+P and C+P+S, with no apparent advantage from using double ridge or straw mulch. For soil and water conservation, C+P+S was more effective than C+P, suggesting the former would achieve the best combined performance of increasing yields and improving soil and water conservation. However, it has not been possible to quantify the magnitude of these conservation benefits under the conditions existing in the catchment. The additional inputs required for C+P+S (INCOPLAST), in terms of straw mulch and labour to install the double ridge compared to the single ridge, could only be justified on technical grounds if achieving improved soil and water conservation was a high priority; (viii) increased yields obtained from the use of polythene mulch, with or without straw, were maintained over four years. Therefore, the technique appears to be agronomically-sustainable in the short-term, but more prolonged monitoring is necessary to determine long-term effects on soil fertility and structure and (ix) relatively high maize yields obtained in this study (more than twice the average yield in Yunnan Province) were achieved through the use of high levels of manure and inorganic fertilizers, with irrigation supplied when necessary to offset early season drought. Detailed cost-benefit analysis attempted to determine if the more labour-intensive techniques and additional inputs required by the most effective cropping techniques (in terms of crop productivity and/or soil conservation) are offset by the value of increased yields (Cuddy *et al*. 2004). This was achieved by socio-economic studies in Kelang village (Fig. 6). Although agronomic measures did enhance productivity and decrease soil erosion, there is strong evidence that farmers are unlikely to implement these practises without significant government support. In particular, investment measures, which have a medium to long-term payback period, will not be implemented without significant assistance from public authorities. These outcomes follow from the fact that maize production is relatively marginal to the total integrated earning activities of farm households, where 45% of income comes from off-farm activities, while rice (*Oryza sativa*), and particularly tobacco (*Nicotiana tabacum*), give a much higher return per labour unit. The critical factor is the 'opportunity cost' of labour. If significant off-farm employment exists at a wage above potential earnings from maize production with the new management practises, then the consequence will be that new practises will not be embraced.

Fig. 6. Kelang village was studied to evaluate the socio-economic effects of changed cropping practises

Agroforestry systems have considerable potential for sustainable economic development, especially the growth of sweet chestnuts. However, projections are that it will take at least five years before these techniques are profitable. Therefore, government assistance is necessary to match the 'time horizons' of farmers and government. Typically, government plans are over periods of five years plus, while farmers have a much shorter planning period. These 'time horizons' are especially short with poorer farmers (Cuddy *et al*. 2004).

2.5. Phase 3: Study extension to the Highlands of Thailand (The Pang Mapa Study)

A parallel study to the Wang Jia Project scientifically evaluated agronomic and physico-chemical impacts of improved agronomic techniques in the highlands of north-west Thailand (Panomtaranichagul *et al.* 2001; Panomtaranichagul and Fullen 2002, 2003) (Fig. 7). This sub-project tested the broader applicability of the cropping and soil conservation practises developed at Wang Jia, for other areas of South-East Asia. The experimental site, located near Jabo village, Pang Mapa District, Maehongson Province (19°33'47"N, 98°12'9"E, altitude 783 m), consists of 12 plots, each measuring 6 × 40 m (240 m^2), on slopes ranging from 30–35% (19–23°). Soils of this experimental site are similar to those of Wang Jia, in that they are developed on limestone, have high pH and are fully base-saturated.

Fig. 7. Field experiments in Pang Mapa, Thailand

During 1999, the SHASEA team designed cropping systems based on the best management practises of both Chinese and Thai agriculture. Chinese systems (ridge tillage, contour cultivation, plastic mulch and INCOPLAST) were modified and adapted to Thai conditions, particularly with the use of local alley cropping techniques. These techniques were applied to the Pang Mapa plots during the 2000–2002 cropping seasons.

The studied cultural practises were: (i) improved traditional highland cultivation adopted in Thailand, contour planting (CC); (ii) modified conventional practise used in China, contour double ridge without mulching (CR); (iii) the novel cultural practise developed in south China (contour double ridge with polythene sheet mulch on the ridges and rice straw mulch in the furrows, CRP or INCOPLAST) and (iv) selected alley cropping, with hedgerows of mango (*Mangifera indica*) trees and ground cover with Graham Stylo (*Stylosanthes guianensis*, AL). The cropping sequence consisted of maize, followed by lablab bean). The experiment had a Completely Randomized Design (CRD) with three replicates of the studied cultural practises.

The results show that both alley cropping (AL) and contour ridge cultivation with mulching (CRP or INCOPLAST) gave better yields of maize and lablab bean than either conventional contour planting (CC) or contour ridge cultivation (CR) during the three growing seasons, 2000–2002 (Table 5). The highest maize seed yields were obtained in AL plots (9.5, 9.9, 10.2 kg ha^{-1}), while the highest lablab bean yields were found in CRP plots (251, 376, 358 kg ha^{-1}) during the three experimental years (2000, 2001 and 2002, respectively). AL also gave the highest water use efficiency (WUE) for maize yield production during the wet season, while CRP had the highest WUE of lablab bean yield production during the dry period. The lowest maize yields and WUE in 2000 and 2001 were found in CR and CC plots, respectively. CR gave the lowest lablab bean yields and WUE in both 2000 and 2001, while CC gave the lowest values in 2002, compared with the other treatments. These

Table 5. The mean dry weight of crop yields and water use efficiency at Pang Mapa based on seed, seed+cob(pod) and total dry matter (biomass) yields of maize and lablab bean produced under different contour cultural practises during the 2000–2002 growing seasons (source: M. Panomtaranichagul, unpublished data) (Notes: a, b, c and d represent differences between the means, significant at $P < 0.05$. Values with the same letter are not significantly ($P > 0.05$) different)

Dry Yields and Water Use Efficiency (WUE)	Conventional Cultivation (CC)			Contour Ridge (CR)			Contour Ridge with mulching (CRP)			Alley Cropping (AL)		
	2000	2001	2002	2000	2001	2002	2000	2001	2002	2000	2001	2002
Maize dry yields (Mg ha^{-1})												
Seed Yield	7.6b	6.2c	8.4b	6.8c	6.7c	8.9b	7.8b	9.1b	9.0b	9.5a	9.9a	10.2a
Cob + Seed (sampling)	9.0b	7.5c	10.2b	8.0c	8.1c	10.8b	9.2b	11.0b	11.1b	11.1a	11.9a	12.2a
Total Dry Matter	15.2c	15.1d	16.7c	13.7d	18.2c	16.4c	16.0b	23.1b	18.1b	18.0a	26.9a	19.0a
Maize water use efficiency (WUE, kg ha^{-1} mm^{-1})												
Seed -WUE	13.3b	10.1b	12.7b	11.7c	11.0b	13.0b	12.5b	16.7a	13.1b	15.4a	16.6a	14.6a
Cob + Seed-WUE	15.7b	12.2b	15.4b	13.8c	13.3b	15.8b	14.8b	20.2a	16.1b	18.0a	20.0a	17.4a
Total Dry Matter -WUE	26.6c	24.6c	25.2b	23.6c	29.9b	24.0c	25.7b	42.4a	26.3ab	29.3a	45.1a	27.1a
Lablab Bean (kg ha^{-1})												
Seed Yield	182c	272c	210d	149d	224d	295c	251a	376a	358a	213b	320b	325b
Pod + Seed	259c	388c	296c	204d	306d	419b	346a	519a	513a	286b	429b	493a
Total Dry Biomass (t ha^{-1})	1.35b	2.02c	0.85c	0.74c	1.12d	1.18b	1.92a	2.88a	1.45a	1.58b	2.38b	1.56a
Lablab Bean water use efficiency (WUE, kg ha^{-1} mm^{-1})												
Seed-WUE	0.53b	0.63bc	0.51c	0.48b	0.51c	0.71b	0.75a	0.85a	0.86a	0.64ab	0.73ab	0.79a
Pod + Seed-WUE	0.76bc	0.90b	0.72c	0.66c	0.70c	1.01b	1.04a	1.18a	1.24a	0.86b	0.99b	1.19a
Total Dry Matter -WUE	3.95c	4.67c	2.05c	2.40d	2.55d	2.84b	5.76a	6.54a	3.50a	4.73b	5.48b	3.77a

results indicated that CRP was the best cultural practise, compared with other treatments, in terms of improving crop yields after the rainy season. This was confirmed by the highest WUE of lablab bean on the CRP plots compared with the other practises. This result was supported by the highest stored soil water within the root zone, decreased evaporation, improved soil properties, decreased soil loss and decreased nutrient loss by deep drainage caused by CRP during the three experimental years, 2000–2002 (data not presented).

Some uncertainty remains over the effects of INCOPLAST on hydrological processes. Field observations in Thailand suggest the mulched furrow is the main infiltration zone, rather than the crop pit. Therefore, a single ridge may be as effective as a double ridge. This was dependent on rainfall intensity and crop growth stages. High rainfall intensity could cause high surface runoff due to water cascading from plastic sheets. Questions remain on the interactive effects of the system on infiltration, runoff, soil moisture, soil water storage, leaching and evaporation rates and processes.

CRP or INCOPLAST may cause degradation of the surface soil structure, because it requires annual reconstruction of the contour ridges. Furthermore, polythene sheets may cause long-term environmental problems. Therefore, contour ridge cultivation practises may not sustain soil quality and soil productivity. On the other hand, alley cropping has many advantages for sustainable crop production. It significantly reduced surface runoff and soil erosion, encouraged the gradual formation of terraces and increased soil water storage. Alley cropping also facilitated recycling of plant nutrients from cut hedgerow crops, which were then used as mulching for the alley crop. Therefore, combinations of the INCOPLAST and alley cropping treatments may be the best cultural practise. Furthermore, these systems may promote carbon-sequestration into soils (Booth *et al.* 2008). The SHASEA research team believes the interchange of research information between China and Thailand will, ultimately, be beneficial for sustainable development in the highlands of South-East Asia.

3. Multiple benefits of the SHASEA Project

Collation of the experimental data draws together several items for discussion, which should assist future similar studies focusing on the development of sustainable agro-environmental systems in tropical and subtropical highlands. Firstly, where the priority is to increase maize yields on sloping land under conditions where the risk of soil erosion is low, contour planting with single ridge polythene mulch is recommended. Secondly, where the risk of soil erosion is higher, but rainfall is likely to be limiting early in the growing season and irrigation water is available for application prior to the application of polythene mulch, the INCOPLAST technique is recommended. Thirdly, on steep land where erosive rains are likely in the early or throughout the rainy season, alley cropping should be applied (with straw mulch if sufficient straw is available). Finally, where these techniques are adopted, straw must be readily available to be applied as a mulching material. However, in all cases, the availability of sufficient manure and straw may be major constraints. The availability of sufficient water for early season irrigation will also be a constraint when rainfall in May and June is considerably below average.

Soil and water conservation benefits of polythene mulch, plus intercropping with soybean, have not been evaluated in this study but, if the effects are similar to those of INCOPLAST, this practise may be recommended where soybean production is important, without sizeable reductions in maize yields. However, soybean yield is less reliable than maize. It has been demonstrated that maize productivity can be increased ≤50%, compared to traditional methods on sloping fragile land, using simple cost-effective technologies, which in parallel plot studies have been shown to improve soil and water conservation. Detailed scientific evaluation has been conducted in Wang Jia Catchment to quantify the effectiveness of these technologies and develop explanations of how crop responses have been produced.

Improvements in maize cropping practises have been linked to a land management plan to develop a more sustainable agricultural system in Wang Jia Catchment. This has included a range of engineering measures to control erosion, installation of an irrigation system to improve reliability and crop yield (including maize and winter wheat), tree planting as cash crops (sweet chestnut and prickly ash) on steeper slopes, pine tree planting on the upper catchment to return land to forestry and the development of a monitoring system to evaluate the effectiveness of these measures over the longer-term.

The land management plan has been based on a comprehensive survey and description of the biophysical catchment characteristics. This has provided a baseline for subsequent change and, furthermore, established the representativity of the catchment in relation to the surrounding area. The catchment has been shown to be representative of its montane region, and the soils at the different sites are representative red soils, dominated by the influence of limestone and strongly affected by contributions from material further upslope. Such areas are extensive in the highlands of Yunnan Province. Site descriptions and analyses are ongoing, as changes to the catchment proceed. These are being developed into a GIS-based land management and evaluation system for other subtropical highland catchments, similar to Wang Jia.

The SHASEA Project was subject to an independent late-stage and post-project evaluation (Subedi 2006; Subedi *et al.* 2009a, b). The Project was successful in achieving its short-term scientific and technical objectives, but was too short to determine the level of adoption by local farmers. Participatory approaches were used wherever possible; including detailed household surveys, participatory rural appraisal (PRA) workshops and discussions with key informants. Field surveys and direct observations were also made, together with a limited economic analysis of the modified cropping practises introduced into the catchment.

Subedi (2006) and Subedi *et al.* (2009a, b) found that farmers had different perceptions about the range of introduced practises. Some were clearly preferred, such as contour cultivation and were likely to be adopted, while others were deemed inappropriate, such as straw mulching and intercropping, and were unlikely to be adopted. The benefits of INCOPLAST were not fully appreciated by the farmers. Other practises would only be adopted if the financial returns were favourable, such as the use of polythene mulch. Longer-term measures, such as tree planting schemes, were regarded favourably, but adoption would still depend on economic returns and related issues such as land security. The farmers suggested an irrigation scheme but, after installation, it was not used extensively for the staple crops in the catchment. It was found that farmers planned to use the irrigation for higher value crops, such as tobacco, after the completion of the Project.

Subedi (2006) and Subedi *et al.* (2009a, b) concluded that, despite the technical and scientific success of the Project, long-term adoption of many practises introduced into Wang Jia will be low, unless considerable incentives are used or much more effective dissemination techniques are employed. It is also considered that the outcomes would have improved considerably if participatory approaches had been used from the outset, to engage farmers more fully with the Project, to ensure that the practises introduced were as appropriate as possible, to achieve greater ownership of the objectives and outcomes, leading to higher adoption rates. More emphasis should have been given to the dissemination of the outcomes at farmer level, outside the study catchment and there should have been more involvement with regional policy makers and extension officials throughout the programme. Longer-term improvements in sustainability at the catchment level have not yet been demonstrated.

4. Discussion

Specific project design and management lessons can be gained from the SHASEA Project, which can be employed by similar research projects promoting sustainable agro-environmental development in tropical and subtropical highlands. A core thesis of the research project was that environmental protection and socio-economic development are complimentary, synergistic and achievable aims. These aims can largely be achieved by adopting holistic and integrated approaches to soil conservation. While soil conservation is largely an environmental engineering problem, we need to recognize that effective conservation has social, economic, educational and political dimensions. Specific lessons from the SHASEA Project include:

1. There has been a tendency to view research programmes as perceived wisdom from the 'industrial north' donor countries being bestowed on the 'developing south.' However, experience stresses the importance of both 'north-south' and 'south-south' co-operation in development projects. Positive examples include the pooling of experience between Chinese and Thai scientists in developing viable solutions for agro-environmental problems in the highlands of South-East Asia.
2. To achieve success, local people must be integrated as full partners in the research programme. This should include genuine consultation and feedback of research information between stakeholders and the research team. Scientists can learn much from the knowledge-base of local communities and stakeholders need to see tangible benefits from the project.
3. A recalcitrant problem is that of addressing 'time horizons.' Farmers usually have short time horizons (i.e. a cropping season or even less), while government policy tends to be much longer-term (five years plus). Matching these different aspirations poses many challenges to the development of appropriate policies. Intermediate term 'relay' strategies are necessary to enable local stakeholders to continue receiving sufficient income in the transition period to the development strategy achieving full agro-environmental and economic productivity and stability.
4. No one discipline holds the key to these complex issues. Therefore, multidisciplinary teams must be developed to include biophysical scientists and socio-economists. Due to differences in approaches, this can be challenging and, therefore, necessitates regular, continued and persistent dialogue and information exchange.
5. For soil conservation initiatives to be effective, it is imperative farmers' gain income from their activities. Many well intentioned projects have floundered because local farmers do not embrace the developed technologies. While the soil conservation technologies may be technically feasible, they have not been implemented because farmers cannot efficiently gain income by their adoption. This again emphasizes the need to genuinely integrate local stakeholders as full research partners.
6. Parallel studies in China and Thailand indicated that using a combination of modified INCOPLAST with biodegradable mulching materials, and alley cropping with hedgerows of fruit trees may be the best cultural practise for sustainable agriculture on sloping highlands in South China and South-East Asia.
7. Short-duration projects often fail to fully disseminate outcomes due to insufficient time and identify dissemination as areas for future work. In contrast, longer projects, for example the 'Thai-German Highland Development Project (TG-HDP)' and the 'Thai-Australian Highland Agricultural and Social Development (TA-HASD) Project,' which lasted for 18 and 12 years, respectively, were able to disseminate the long-term activities and reported the impact of these activities on the living standards of target communities, farming systems and environ-

mental conditions within the project area. Longer duration projects are able to both commit more time to dissemination and to follow through the processes of adoption and adaptation and possibly achieve greater long-term success. Perhaps it is time for funding agencies to reconsider their tendency to fund shorter duration projects (Subedi 2009b).

8. Education is the key to success. Urbanized societies are becoming progressively remote from the food resource base and generally have vague and sanitized views of agricultural production systems. Educators have a pivotal role to play in increasing knowledge, awareness and understanding of soil system dynamics at multiple levels, from school to University level and to the general public. To achieve long-term success, developing and maintaining 'land literacy' amongst people is crucial.

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ŽEMĖS ŪKIO IR APLINKOSAUGINĖ PATIRTIS VYKDANT PROJEKTĄ „TVARUSIS ŽEMĖS ŪKIS PIETRYČIŲ AZIJOS AUKŠTUMOSE“

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Santrauka

Tvariajai žemės ūkio plėtrai skatinti Pietryčių Azijos aukštumose tarptautinių tarpdisciplininių mokslinių tyrimų grupė ištyrė pasirinktų argonominių bei dirvos apsaugos būdų efektyvumą (taikyta ir modifikuotieji, ir nauji žemdirbystės būdai) dirbamuose ūkininkų laukuose. Tyrimo vietos pasirinktos Junanio provincijoje (Wang Jia baseine) Kinijoje ir Mae Honson provincijoje (Pang Mapa srityje) Šiaurės Tailando aukštumose. Straipsnyje aptariama projekto pamokos, susijusios su bendradarbiavimo plėtojimu, mokslinių tyrimų partneryste, investavimu, tarpdisciplininių metodų taikymu, pajamų augimu, informacijos sklaida ir švietimo klausimais.

Reikšminiai žodžiai: Kinija, šiaurės – pietų bendradarbiavimas, dirvožemio apsauga, *INCOPLAST*, pietų – pietų bendradarbiavimas, šiaudų mulčas, tvarioji plėtra, Tailandas, „laiko horizontas“.

СЕЛЬСКОХОЗЯЙСТВЕННЫЙ И ПРИРОДООХРАННЫЙ ОПЫТ, ПОЛУЧЕННЫЙ ПРИ ОСУЩЕСТВЛЕНИИ ПРОЕКТА «РАЦИОНАЛЬНОЕ СЕЛЬСКОЕ ХОЗЯЙСТВО НА ВОЗВЫШЕННОСТЯХ ЮГО-ВОСТОЧНОЙ АЗИИ»

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С целью содействовать рациональному развитию сельского хозяйства на возвышенностях юго-восточной части Азии группа ученых, занимающаяся междисциплинарными научными исследованиями, исследовала эффективность некоторых агрономических и почвоохранных мер с применением как модифицированных, так и новых способов земледелия на обрабатываемых сельскохозяйственных полях. Для исследований были выбраны места в провинциях Юнань (в бассейне Wang Jia) в Китае и Мае Гонсон (Pang Mapa) на возвышенностях Северного Таиланда. Проанализирован опыт, полученный при осуществлении проекта и касающийся развития сотрудничества, партнерства в сфере научных исследований, инвестирования, применения междисциплинарных методов, роста доходов, распространения информации и вопросов просвещения.

Ключевые слова: Китай, сотрудничество между севером и югом, почвоохранные меры, INCOPLAST, сотрудничество между югом и югом, соломенная мульча, рациональное развитие, Таиланд, «горизонты времени».

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