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Diagnosis on Thai agrarian Systems for Research Prioritization to improve the Sustainability and Competitiveness of Cotton Production

Jean-Christophe Castella[1], Guy Trébuil[2], and Yves Crozat[3]

ABSTRACT

Since 1980, cotton production in Thailand has been decreasing steadily while the demand for cotton lint from the national textile industry jumped dramatically. Attempts made to raise again cultivated areas and yields were not able to alter significantly this declining trend. To understand the factors and conditions determining such an unfavorable evolution, diagnostic studies on cotton production systems were carried out by the Development-Oriented Research on Agrarian Systems (DORAS) project at the complementary field, farm and regional scales.

Interdisciplinary teams implemented regional historical analyses and zonations, farming systems characterization and classification, as well as cropping systems surveys and experiments at two contrasted sites: the Maenam Kwae Noi valley in Kanchanaburi province and Chaibadan district of Lop Buri province.

While insect pests were found to be the most important cause of cotton production declining sustainability and competitiveness at both sites, the findings suggest that the suitable ways to improve the current situation will differ at these two locations. While in the old cotton producing belt of Chaibadan, significant progress can still be achieved through technical improvements in pest, crop and labor management, in Kanchanaburi border area the social status of the migrating Mon cotton growers, very dependent on entrepreneurial village middlemen, makes organizational and social innovations a prerequisite to significant technical advances.

An integrated set of agronomic research priorities dealing with cotton plant improvement for pest tolerance and high cottonseed and lint quality, integrated pest management and other decision support tools for better crop monitoring and management came out of these diagnostic analyses and were subsequently used to structure the following phase of DORAS project activities.

Key words : cotton, sustainability, production systems, IPM, Thailand

INTRODUCTION

Before the 1950s, cotton was traditionally grown in Thailand by subsistence farmers for their own needs. The successive steps of cotton industry, from sowing to weaving, were all handled by household members. During the 1950s, Thai farmers were able to supply all the raw cotton needed by the burgeoning national textile industry. The average annual domestic consumption was about 8,000 tons of lint (Grimble, 1971). Since that time, textile mills have steadily increased their consumption of cotton and in recent years have been using around 400,000 tons of lint annually. The textile sector reached the top rank of the country foreign exchange earner during the 1980s. However, the rapid expansion of the industry relied heavily on imports of raw cotton lint (worth 16 billion bahts in 1994), as an irregular and declining

1 Institute de Recherche pour le Développement (IRD), France.

2 Centre International en Recherche Agronomique pour la Développement (CIRAD), France.

3 DORAS Center, Kasetsart University, Bangkok 10900, Thailand.

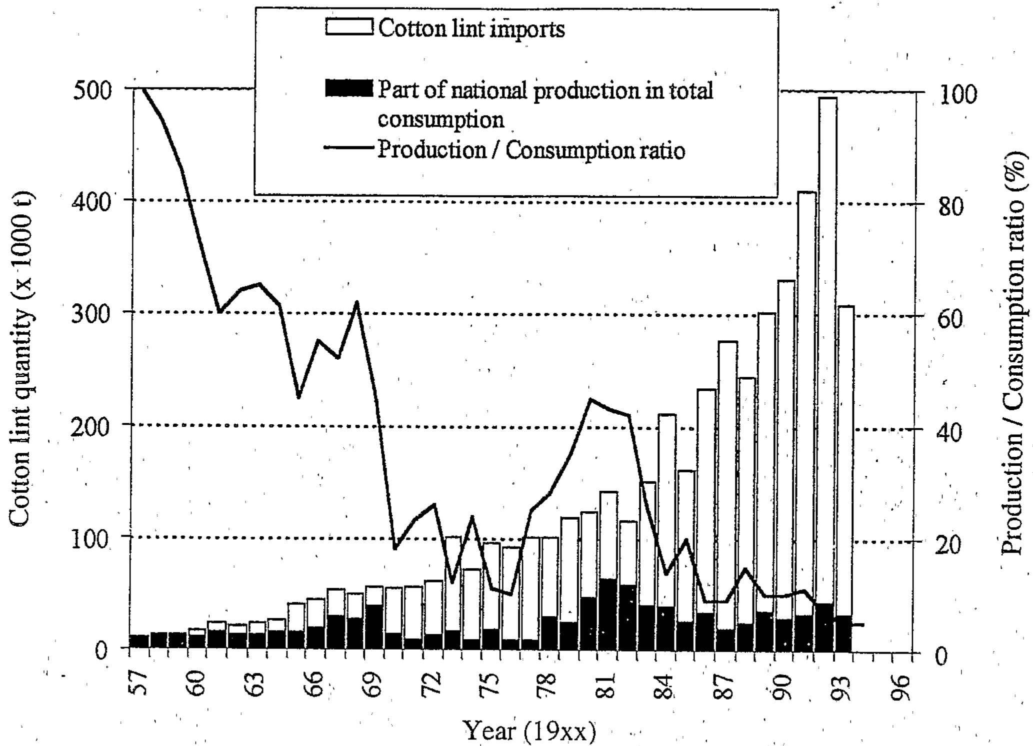

Figure 1 Evolution of the national cotton lint production and the cotton lint consumption by the Thai textile industry.

Sources : Office of Agricultural Economics, Ministry of Agriculture and Cooperatives & Division of Textile Industry, Ministry of Industry.

domestic production failed to keep pace with the rising demand (Figure 1). Despite continuous efforts by concerned government agencies to reduce this dependence on imports (Evenson, 1987; Castella, 1995), today the national production is still limited to 10% of its consumption. In such a context, in the early 1990s the Development-Oriented Research on Agrarian Systems (DORAS) project at Kasetsart University decided to conduct diagnostic surveys to elucidate the complex system of biophysical and socio-economic factors and conditions that led to the recent crisis of the national cotton industry, as well as to identify ways to improve the ecological sustainability and economic competitiveness of Thai cotton production systems.

MATERIAL AND METHODS

From 1991 to early 1994, DORAS project implemented in-depth diagnostic studies on the agrarian systems of the Maenam Kwae Noi valley, Kanchanaburi province, and Chaibadan district, Lop Buri province (Figure 2). The general methodology (Trébuil, 1992; Trébuil and Dufumier, 1993) was based on an holistic and historical systems approach of agrarian, farming and cropping systems at the complementary scales of the region, the household and the field. At each level of the systems hierarchy, attention was called upon the interactions between technical, ecological and socioeconomic phenomena. Starting from the more embodying level, interpretation of information gathered at a given scale was constantly facilitated by the understanding of phenomena uncovered at

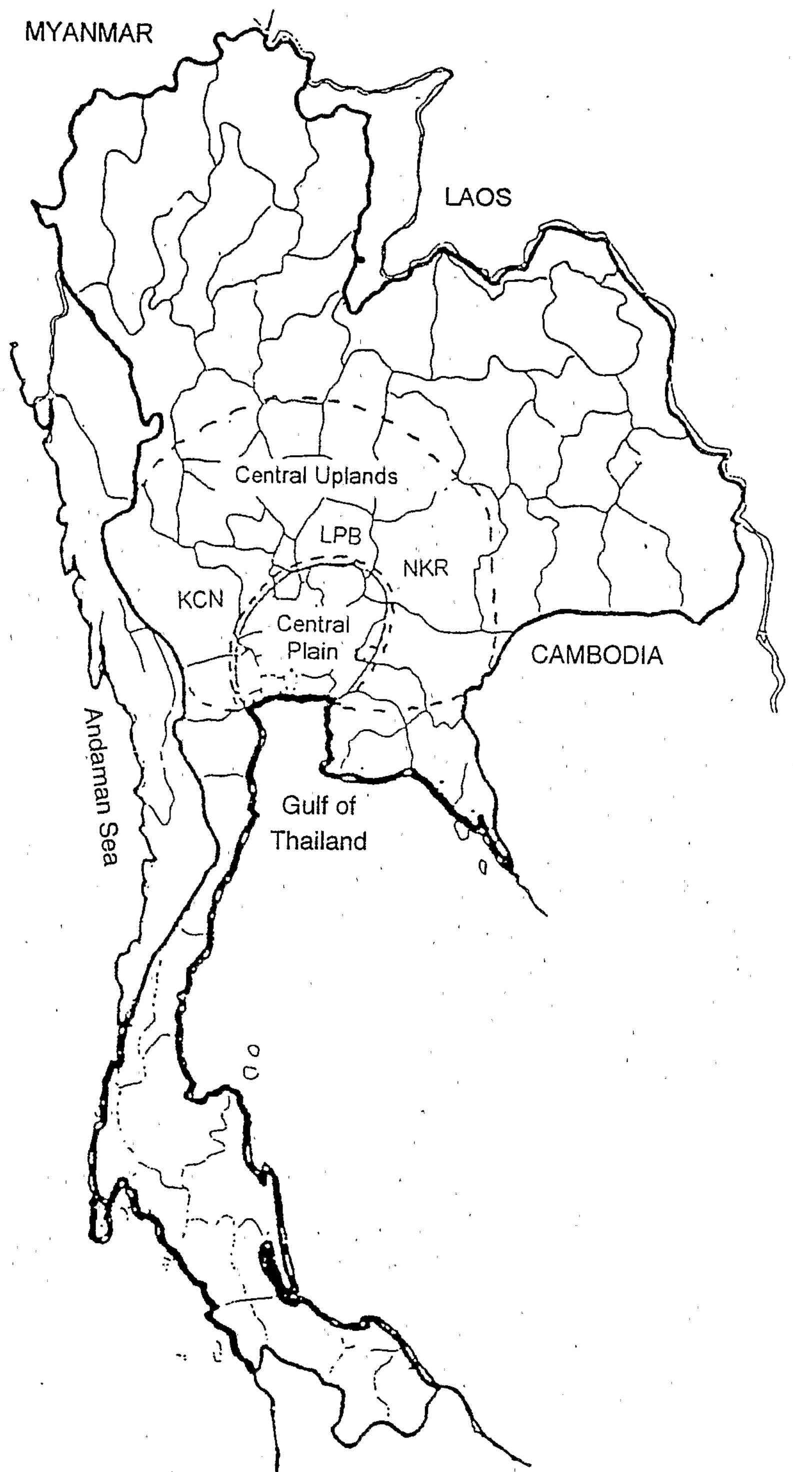

Figure 2 Location of DORAS project research sites in the upland areas surrounding the central plain of Thailand: Kanchanaburi (KCN), Lop Buri (LPB) and Nakhon Ratchasima (NKR) provinces.

the previous level. The following successive steps of the diagnostic analysis were implemented.

1. Zonations of target areas

Based on secondary data, complemented by the runs of well-selected transect lines crossing the most important heterogeneities observed in the organization of landscapes, the delimitation of relatively homogeneous zones was attempted. For each of them, agroecological and socioeconomic potentialities and constraints that could influence the choice and evolution of cropping and farming systems were assessed. A key result of this first step is the characterization and location of the main agricultural technical systems used by farmers in producing and exploiting agroecosystems (Trébuil *et al.*, 1994).

2. Understanding of recent ecological, technological and socioeconomic transformations

Informal interviews with key witnesses (old farmers, village headmen, merchants, agricultural extension officers, monks, etc.), focusing on recent changes in the local agricultural sector, were carried out to build a chronology of key phases in the history of agricultural development in order to understand the origins, possible causes, extent and consequences of farmers' situations and current problems (Trébuil *et al.*, 1994). The driving forces of recent agrarian transformations were also identified at this stage, as well as hypotheses on how and why farmers modified the place of the cotton crop in their whole farming systems according to their access to land, capital, labor and other means of production, but also depending on the organization and evolution of the local social relations under which they have to operate.

3. Characterization and classification of diverse farming systems

Based on this understanding of the extent and origin of the diversity of farming situations in the area, a limited sample of households covering most of the identified variability of farming circumstances was selected for interviews aiming at an understanding of:

- The functioning of these farming systems: their socio-economic objectives and related strategies, their key management criteria, the characteristics and performances of their production systems, and
- The role-played by the cotton crop in each of them.

Later on, by comparing the sets of farmers' objectives and strategies identified, farming systems were grouped into a typology in which different types of systems are assigning different roles to the cotton crop. Key indicators were finally selected for a rapid assessment of the frequency of each kind of farming systems included in the typology.

4. Monitoring surveys of cotton cropping systems and on-farm experiments

Cotton fields belonging to farming systems characterized in the previous step were monitored during two successive crop years to understand the diversity of farmers' practices and to check their coherence with the proposed functioning of the whole farming system. Complementary and simple on-farm experiments were also implemented to assess seed cotton production potentials and to improve our understanding of the variability of technical performances observed in farmers' fields. Data gathered at field level were then used to quantify yield losses and to grade the limiting factors of the cotton crop (Castella, 1995).

Because the presentation of field level results does not constitute the main objective of this article, only several data obtained at this scale will be presented.

It is based on this assembled multiscale set of agronomic and socioeconomic information obtained from the diagnostic analysis that the prioritization of cotton research topics to improve cotton production systems was subsequently carried out.

RESULTS AND DISCUSSION

1. Role of the cotton crop in agricultural development of the central uplands

The recent history of Thai cotton production is linked to the development of the ring-shaped upland agricultural region surrounding the irrigated central plain (Figure 2).

Natural resources and climate. The regions concerned by this study are dominated by undulating to rolling uplands, from 100 to 400 m. above sea level. Soils are inherently fertile, high in pH (favoring cotton growing), but present certain problems in soil management owing to their stickiness and adhesive nature when wet and their hardness and cracks when dry (DLD, 1972). A bimodal rainfall distribution, with a peak in May and another in September, allows to grow two (up to three in some areas) successive crops per year on the same plot of land during the approximately 6 month long rainy season. Total precipitation range from 1,000 to 2,000 mm per annum.

Agricultural dynamics. Before the opening up of these areas to permanent cultivation by migrant settlers, they were covered by a mixed deciduous or dry evergreen forest populated by large wild animals (deer, elephant, etc.). A simplified chronology of the artificialization of the ecosystem can be summarized as follows:

1950 - 1965: an advancing pioneer front and new settlements. The first wave of settlers opened the forest starting from communication infrastructures (railways in Kanchanaburi, river then laterite roads in Lop Buri) and then advanced farther from them. They cleared manually a light secondary forest or bush already degraded by logging companies, charcoal manufacturers or slash-and-burn cultivators. Migrants were coming from densely populated flood plains and valleys of lowland Thailand where land shortages occurred. As only manual tools were available, only part of the encroached land was put under cultivation. Agricultural production, aiming at self-sufficiency, consisted predominantly in upland rice and traditional vegetables production. As those areas became less isolated from markets, the development of high yielding crop varieties suitable for rainfed upland areas, particularly maize and cotton helped to raise farm incomes and to attract more potential settlers from the lowlands. The changing price ratio of upland crops and rice, in favor of the former, encouraged farmers to adopt upland cash crops.

1965 - 1980: socio-economic consolidation and expansion of labor extensive production systems. Interactions among migrants participating in the agricultural colonization increased leading to self-organization in villages. The process was supported by the government policy which provided social infrastructures (administrative offices, schools, etc.), improved malaria control, and constructed roads through the regions. The introduction of farm tractors in those areas during the early seventies allowed double cropping of heavy upland soils, something that could not have been done by using hoes or draft animal plows alone. Such heavy mechanization promoted by entrepreneurial village middlemen, even in remote areas, encouraged the development of labor extensive production systems relying on the increase of the land/labor ratio more than on yield improvements to increase returns from cotton production. The first agricultural inputs (mainly fertilizers and insecticides) were distributed by the middlemen together with cotton seeds of introduced varieties. Seasonal credit was mainly provided by them as well as most of the farmers could not have access to official money lending institutions in the absence of land titles to be mortgaged.

By the second half of the sixties, the growth of harmful cotton insect populations was such that yields and returns were seriously reduced. Cotton growers switched to other rainfed upland crops, already dominant in the landscape, cereals (maize, that represented approximately 75% of cultivated area against 5% for cotton in 1969, sorghum) and grain legumes (soybean, mungbean and groundnuts). Most of these alternative crops, although only capable of producing relatively low returns per hectare, proved to be less risky and required substantially less labor. At the same time, at national level, the drop in acreage under cotton in what became permanently cultivated areas was partly counterbalanced by the expansion of new areas along the advancing pioneer front. Because insect pests do not present a serious problem during the first years of cultivation, the possibility to open new land to cotton production was attractive.

1980 - 1995: diversification, intensification and increased differentiation among production systems. By the early eighties, regional shifts in cotton cultivation had explored all the available land and the pioneer fronts had reached marginal areas less suitable for cotton production. Fortunately, the release of pyrethroid insecticides provided a very timely and efficient protection against cotton bollworm populations, as most of them were becoming resistant to the previous generation of insecticides. The subsequent intensification of cotton systems, encouraged by this major technical innovation and also backed by government incentives (integrated cotton projects, extension services, credit facilities, etc.), was stopped after only three years by new insect pest resistance. Farmers returned again to less risky alternative crops, such as soybean, cereals or sugarcane (Figure 3). The most indebted farmers had no choice but to sell their land and to increase the flow of wage earners leaving rural areas to be attracted by the booming industrial and construction sectors of the Bangkok region. By the early nineties, the rural exodus had triggered a social differentiation in the countryside characterized by the emergence of five main types of actors (A to E types in Figure 4) involved in agricultural activities:

- Middlemen got back mortgaged land from indebted farmers. They invested in perennial crops (E type) such as fruit trees or eucalyptus plantations or/and installed landless farmers (A1 type) to cultivate their land.

- A new type of farmers (B1 type) appeared in Kanchanaburi area, most of them being Mon ethnic migrants from Myanmar who are socially and economically dependent on middlemen. They practice the maize-cotton relay cropping system and rely on local merchants for the procurement of inputs, provided at the cost of high credit rates (3 to 5% per month), and for technical advice.

- Farmers who could benefit from the

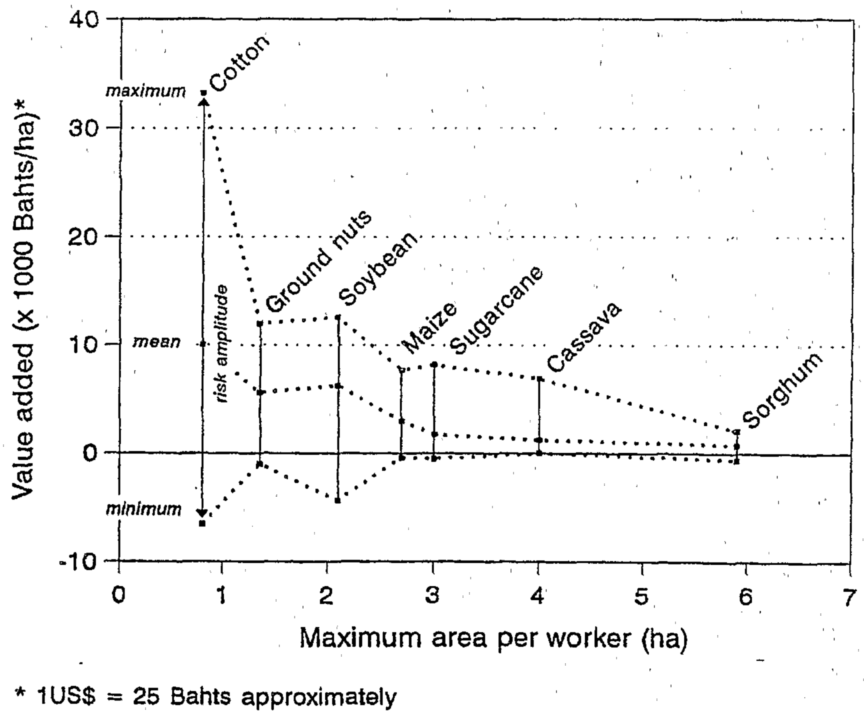

Figure 3 Comparison of productivity, economic risk and labor requirement for the crops commonly grown in rainfed agricultural areas of Lop Buri province.

Sources : On-farm surveys in Chaibadan district, Lop Buri province, from 1992 to 1994.

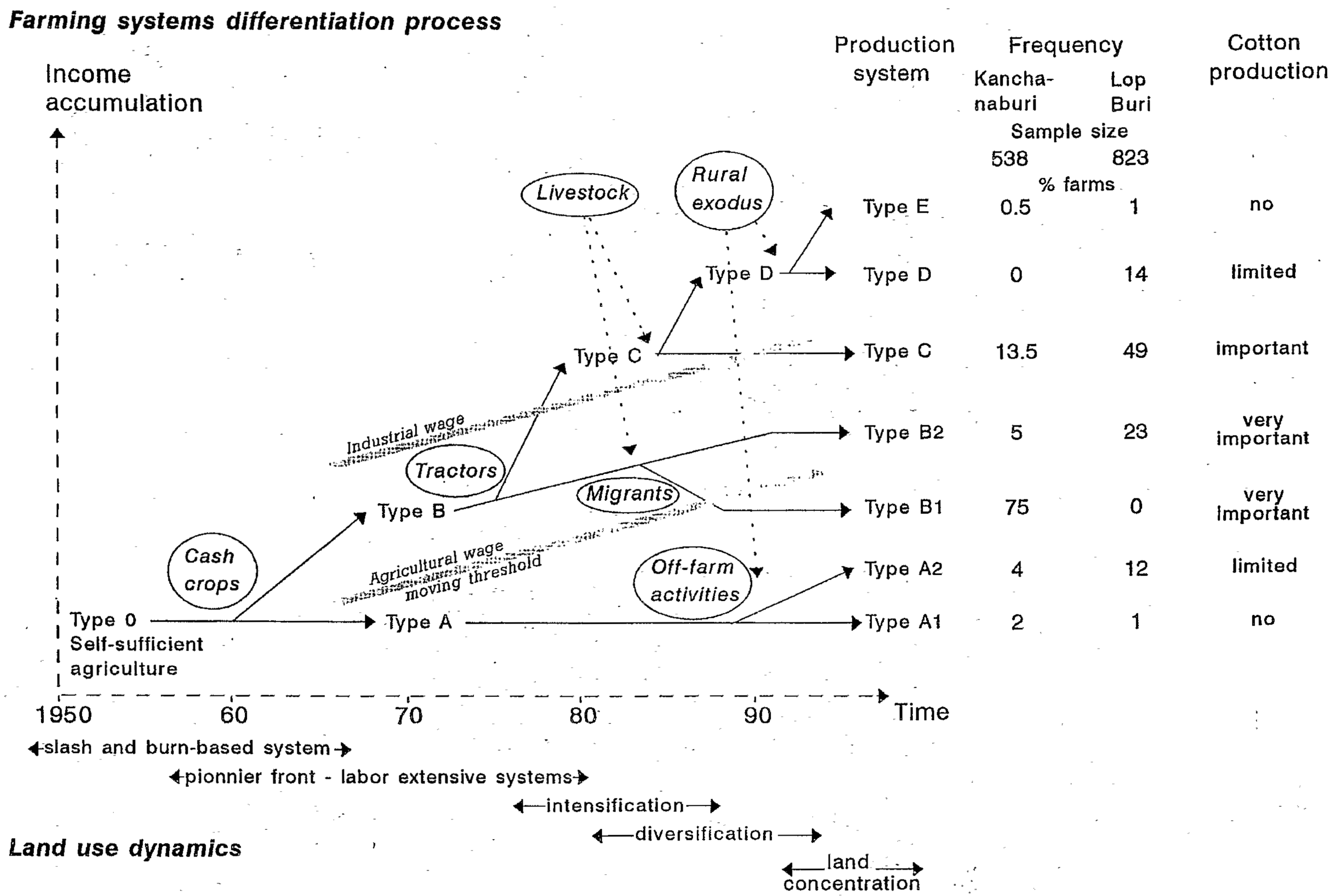

Figure 4 Trajectories of evolution of farming systems at Kanchanaburi (KCN) and Lop Buri (LPB) research sites.
Sources : On-farm surveys, DORAS Project.

previous period of cotton boom to increase their farm size and improve mechanization (usually early settlers) tend to specialize in a few number of labor extensive cropping (C type) or animal husbandry activities (D type).

- Some smaller farmers (B2 type) continue to grow cotton as it still provides the highest potential return per land unit among upland crops, but only on a part time basis for some of them (A2 type) as they turn their interest toward more off-farm activities to improve their incomes.

- The fifth types of actor often provide small farmers with local temporary employment. In the early nineties, some Bangkok-based companies (E type) purchased large pieces of land to develop tourism-based activities (golf courses, resorts, etc.) or large scale agribusiness enterprises (commercial forests, cash crops, chicken, and swine or cattle farms). Land speculation became a major driving force of agricultural transformations, by making land price non-affordable anymore by household-based farms.

2. Cotton growing, environmental transformations, and crop protection problems

Concomitant to agricultural development, important natural resource depletion occurred during the last 40 years.

Deforestation, biodiversity depletion, and composition of the entomofauna

The forest clearing process has been continuous since the fifties, allowing a three-fold increase in the national agricultural land between 1950s and 1990s. Today, only marginal areas of stony or steepest land, and protected areas have been left vacant. Presently, forest areas cover 31% of Kanchanaburi province, against 80% in 1970s. Moreover, only 3% of Lop Buri province were covered by forest in 1990s.

Subsequent erosion as well as climatic changes witnessed by farmers forced them to adapt gradually their cotton management practices to new environmental conditions (Castella, 1995). In the early 1990s, the reduction of rainy season duration led farmers to shorten crop cycles (selection of early maturing, or drought tolerant varieties of maize, sorghum and cotton), to increase the relay period between successive crops (lowering both crops yield potentials), or even to grow only a single crop per year on the same plot of land.

The evolution of the cotton insect pest complex in Thailand is associated with the above-mentioned process of artificialization by mankind of its natural environment. The natural equilibrium which prevailed in the forest ecosystem through complex insect regulations was first disturbed by land clearings and rapid extension of maize - cotton relay cropping systems (Grimble, 1973). Lawson (1979) quoted by Evenson (1987) showed in Lop Buri area that the first bollworm generations observed on cotton early in the season came from maize fields. The rise of *Helicoverpa armigera* populations to the status of major pest may also be partly explained by the relative importance of maize and cotton cropping systems in the ecosystem. Overlaps in crop calendars allow eight to nine bollworm generations to develop over a nine months 'humid season', first on maize, then on cotton, soybean or vegetables, and finally on sorghum or weeds. In Kanchanaburi area, the 20 to 40 days long relay period of the maize - cotton-cropping system allows a direct transfer of bollworms between the two crops. In Lop Buri, insect pest's migration is necessary, as both crops are grown as monoculture.

Insecticides, insect resistance, and pest population dynamics

The first use of insecticides can be dated back to the late fifties when farmers faced heavy crop losses caused by outbreaks of the Bombay Locust (*Patanga succincta*) (Jalavicharana, 1969). Massive DDT aerial sprays were conducted by the Department of Agriculture. Malaria eradication programs also applied the same technique over large areas.

However, up to the early sixties, farmers did not use pesticides and relied exclusively on cropping practices, natural biological control and host plant resistance to control pests (e.g. selection of cotton cultivars tolerant to bacterial blight and leaf roll virus). The first widely used agricultural pesticides were introduced together with improved cotton varieties. Then, the pest complex evolved depending on the characteristics of cotton cultivars, the nature of insecticides applied by cotton growers and the intensity of sprays (Table 1). Insect

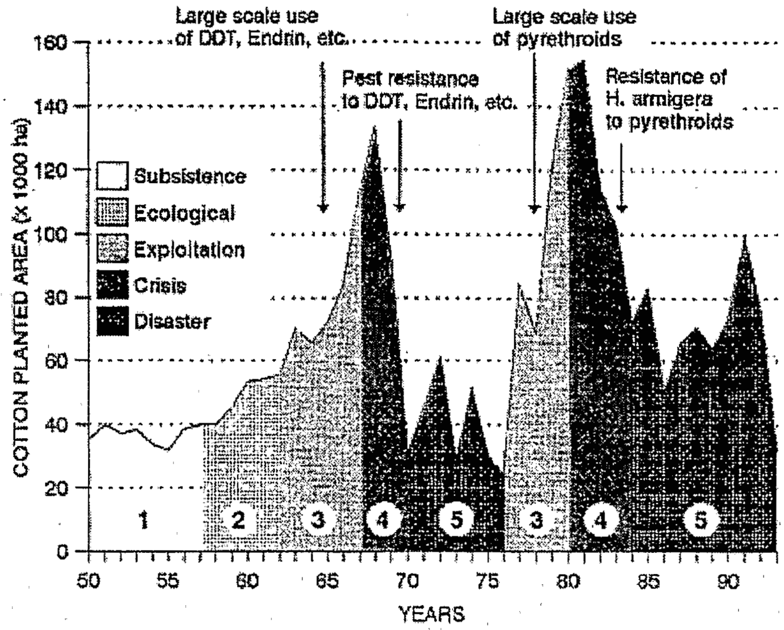

Figure 5 Changes in Thailand cotton planted areas in relation to the successive historical phases in cotton crop protection.

1. *Subsistence phase*: traditional cultivars highly tolerant to pests and diseases.
2. *Ecological phase*: introduction of new cultivars with better productivity and fiber quality but more susceptible to pests and diseases. Breeding for variety tolerance to pests.
3. *Exploitation phase*: high productivity thanks to chemical inputs (fertilizers, insecticides, etc.)
4. *Crisis*: insect pest resistance to pesticides; heavy damages, very difficult to control by chemicals.
5. Stabilization phase after a disaster : discontinuance of less productive cotton growers, promotion of IPM principles.

considered as minor pests gradually became major constraints to cotton production. During the 1962-1963 season, three insects - spiny bollworm, pink bollworm and jassids - were classified as ' very serious' pests (Anthony and Jones, 1963), but of these only jassid has remained of serious importance afterwards. However, jassids were easily controlled and a far greater a problem has been created by the growth of cotton bollworm populations (Deema *et al.*, 1974). In 1962, yields of unsprayed experimental plots at Srisamrong Agricultural Station were approximately 90% of the insecticide protected ones (Anthony and Jones, 1963). By 1970, however, the situation had completely changed and yields on cotton plots which did not receive insecticides against *H. armigera* were virtually nil (Deema *et al.*, 1974). The composition of the cotton pest complex remained almost unchanged until the end of the seventies when pyrethroid insecticides were released. These cheap (because of their low dosage rate) chemicals of low human toxicity were highly effective against *H. armigera* and farmers generally used them for the entire season (Wangboonkong, 1981).

The transformations of cotton entomofauna was characterized by a reduction in insecticide susceptibility due to intensive use of organochlorine compounds (DDT, etc.) in the early seventies, then again to pyrethroids in the early eighties. The lack

Table 1 Evolution of the cotton insect pest complex in Thailand based on literature review (Beller and Bhenchitr, 1936; Pholboon, 1965; Wongsiri, 1991).

Insect pest (scientific / common name)	1936	1965	1991
Amrasca biguttula Ishida Cotton jassid, cotton leafhopper	Non-pest	Major pest	Major pest
Aphis gossypii Glover Cotton aphid	Minor pest	Major pest	Minor pest
Ayyaris chaetophora Karny Leaf sucking thrips	Non-pest	Major pest	Minor pest
Bemisia tabaci Gennadius Whitefly	Non-pest	Non-pest	Major pest
Cosmophila flava F. Semi-looper caterpillar	Minor pest	Minor pest	Minor pest
Dysdercus cingulatus F. Cotton stainer bug	Minor pest	Major pest	Minor pest
Earias fabia Stoll Spiny bollworm	Minor pest	Major pest	Minor pest
Helicoverpa armigera Hübner Cotton bollworm, American bollworm	Non-pest	Minor pest	Major pest
Pectinophora gossypiella Saunder. Pink bollworm	Minor pest	Major pest	Minor pest
Pempherulus affinis Faust Stem boring weevil	Minor pest	Major pest	Minor pest
Oxycarenus laetus Kirby Dusky cotton bug, cotton seed bug	Minor pest	Major pest	Minor pest
Sylepta derogata F. Cotton leafroller	Minor pest	Major pest	Minor pest
Spodoptera littoralis F. Cotton leafworm	Non-pest	Minor pest	Major pest

☐ Non-pest ▒ Minor pest ■ Major pest

of training in the proper use of insecticides, as well as active commercial campaigns encouraging their indiscriminate use, had led to severe problems of insect resistance (Caron *et al.*, 1995). Many farmers throughout the country complained about the lack of effectiveness of insecticides. This was supported experimentally by data from field trials (Sinchaisri, 1988) as well as laboratory analysis (Collins, 1986). In 1994, the pyrethroid resistance ratio between susceptible and resistant strains of *H. armigera* reached more than 200, and DDT resistance was still very high despite its official ban since 1985. Insecticide resistance was also noticed on other pests such as aphids and jassids (Ouchaichon, 1991).

Thailand cotton protection history exemplifies the concept of a characteristic sequence of five phases in crop cultivation in relation to pest control (Smith, 1969): (1) subsistence, (2) ecology (3) exploitation, (4) crisis, (5) disaster. Falcon and Smith (1973) then Bottrell and Adkisson (1977) showed that elements of this pattern have been identified in cotton growing areas of various countries. Major changes in the areas planted to cotton since 1950s are relatively well-explained by examining the history of insecticide use and the appearance of resistance as shown in Figure 5. Thailand has now passed through these successive phases for the second time in its cotton growing history. Each time the fifth phase was reached, integrated pest management (IPM) was invoked as the ultimate solution to cotton crisis (Deema *et al.*, 1974; Evenson, 1987) but could never be implemented on a large scale by farmers (Napompeth, 1993).

3. The collapse of Thai cotton production industry

Crop protection problems have trapped the whole Thai cotton production sector in a vicious circle of decreasing returns and a complex of multiple constraints, interacting in a mutually reinforcing fashion.

Almost all ginneries worked on very low throughputs or even closed their factories during the low production periods (in the early seventies and again since the early eighties). From 86 ginning factories officially registered by the Ministry of Industry in 1970, only 18 were still operating in 1993. The shortage of seed cotton for ginners had two important consequences on its production. Firstly, in the ginner's attempt to maximize throughput, there has been intensive 'bidding up' in the price paid to the farmer for seed cotton. Secondly, for similar reasons, the ginners have paid little attention to the grade of the cotton purchased or to the quality of the ginning process itself. The ginneries have been working on so low margins that they have cut production costs to a minimum (Kirdpanich, personal communication); worn out gin parts have not been renewed, supervision has been minimized, etc., and the grade of lint has suffered as a consequence. Ginneries have not been able to pass on the higher price of the raw material to textile mills because competition among themselves and from imported cotton has restricted their bargaining power. As a consequence, there is little if any price increment at farm level for high quality seed cotton and there is therefore little incentive for farmers to improve the grade.

Facing this crisis of its cotton production, the Thai government policy was thus torn between two opposing goals. On one hand, it supported domestic production of cotton in order to maintain a relative independence of the textile industry from imports, and in the best case, to bring Thailand to the point of self-sufficiency in cotton lint. Cotton prices were kept high on the domestic market as an incentive for farmers to grow cotton. However, pest control problems raise production costs and the economic risk for growers, leading a lot of them to give up growing cotton. On the other hand, facing chronic cotton shortages on the domestic market, the government was obliged to favor cotton lint imports through low import duty in order to support the rapid expansion of the textile industry. This further decreased the competitiveness of domestic cotton and hampered a possible revival of its production.

Beyond the steadily increasing production costs due to insecticide use, farmers had thus to support the burden of a disorganizing cotton industry. After having avoided crop protection problems through migrations along advancing pioneer fronts, then concealed them by switching to other crops or applying large amount of insecticides. Today, Thai farmers have to develop new strategies to grow cotton on a more sustainable basis. The DORAS Project endeavors to support them in designing technical and organizational innovations that are well-suited to current problems of cotton growers.

SETTING RESEARCH PRIORITIES

Farmers' decision to grow cotton is subject to the cash benefit expected from this production (in comparison to alternative crops) versus the risk of failure due to pest problems. Research activities should contribute to optimize the former while minimizing the latter.

When broken down into its components, the cash benefit from cotton growing can be represented by the following equation:

$$\text{Added Value} = \text{Gross Product} - \text{ProductionCosts} \quad [1]$$

An increase in added value can thus be

achieved through an increase in the first component of equation [1] and/or a reduction of the second.

1. Search for an increase in the value added of seed cotton

The gross product from cotton production can also be broken down as follows :

Gross Product = Yield x Unit Price of Seed Cotton .... [2]

However, an increase in potential yield is unlikely in the near future as there was no significant increase during the last decades despite considerable breeding efforts to increase seed cotton yields. Evenson (1987) noticed that the actual yields are more influenced by crop protection problems than production potential of cultivars (see also Figure 6). Consequently, research priority was given to the improvement of seed cotton quality as a way to increase seed cotton price paid to growers. Such a unit price can be broken down into:

Seed Cotton Unit Price = % Lint Weight x Lint Price + % Seed Weight x Seed Price .... [3]

in which the price of lint is approximately seven fold the price of seeds.

Two ways towards quality improvement were thus tried by DORAS Project:

- Introduction and breeding of cultivars with improved ginning outturn (proportion of lint in seed cotton weight) and high-quality fiber properties,

- Introduction of gossypol-free cultivars for a better valorization of the cottonseed in animal feed or other food industries,

Other key characteristics of these new cultivars (yield potential, resistance to insect pests, etc.) should remain at least at the same level than the one displayed by varieties currently used by farmers.

2. Search for a reduction of production costs

A reduction in production costs could be achieved by lowering inputs and hired labor costs, representing respectively 43% and 31% of average total production costs in 1993 and 1994 in Chaibadan area. DORAS project decided to work on ways to rationalize the use of insecticides as a first step in a gradual move toward IPM systems acceptable to the different types of farming sys-

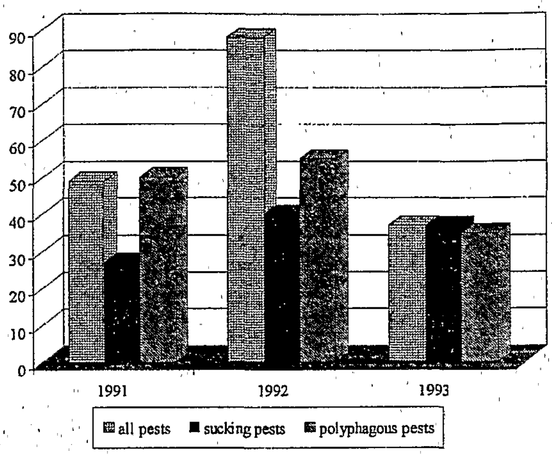

Figure 6 Seed-cotton yield losses due to different types and the whole complex of insect pests observed in on-farm trials with three levels of crop protection in Kanchanaburi and Lop Buri areas (DORAS Project).

tems still involved in cotton cultivation. Research was oriented towards:

- An understanding of the effect of planting dates on insect pest population dynamics,

- The re-introduction of leaf hairiness as a morphological character of natural tolerance against jassids,

- Seed treatments for early protection against sucking insects, while avoiding early aerial sprays and damages to beneficial,

- The definition of relevant and practical economic thresholds for insecticide spraying,

- The use of biological insecticides, alone or in combination with low dosage of chemical insecticides,

- On the longer term, a program for the development of transgenic cotton that will produce Bt toxins has also been launched to produce cotton cultivars more tolerant to major insect pests.

As crop protection cannot be considered independently from other technical operations, research in agrophysiology focuses on the optimization of crop management: cotton pattern of yield build up, evaluation of itineraries of techniques and cropping systems efficiency in relation to pest damages. This work should lead to the elaboration of two types of models: a decision - oriented model based on IPM and plant monitoring to be used for crop management and reduction of input use; and a crop simulation model for research needs such as breeding or designing of mechanized cropping systems.

3. Stakeholder participation: a necessity toward future sustainable cotton cropping systems

The risk of failure can be assessed through the variability in the value added from cotton growing between farms (Figure 7) and between years (Castella *et al.*, 1996). Thus, the search for new technologies adapted to the diversity of farmers' needs and objectives relies on a correct understanding of farmers' management choices. The farming systems typology based on the functioning of agricultural production systems is a reliable tool for such an understanding (Trébuil, 1992). For example, in Lop Buri and Kanchanaburi provinces, Castella *et al.* (1996), have shown that the 'environmentally friendly' techniques promoted by agricultural extension agencies could not be adopted by cotton growers because of socio-economic constraints. Actual implementation by farmers of IPM principles requires a sound understanding of their crop management choices in relation to the potentialities and constraints of their own farming systems, as well as the various and often conflicting interests and strategies of key stakeholders in the cotton industry. Thus, beyond new technologies, organizational innovations and agricultural policies have also to be proposed through coordination between these different stakeholders in the cotton industry. Moreover, recommendations targeted at the various types of farmers should lead to better responses because of the involvement of these end users in the successive phases of their elaboration.

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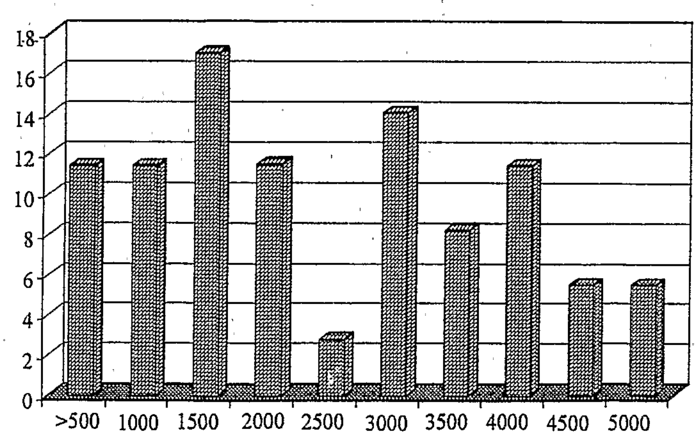

Figure 7. Variability of the gross margin obtained by cotton growers in Chaibadan district, Lop Buri province in 1993 and 1994 (DORAS Project).

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