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A systems approach to understanding obstacles to effective implementation of IPM in Thailand: key issues for the cotton industry

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Abstract

A comprehensive study of the history of cotton production in Thailand shows the causes of its collapse. Crop protection problems are regarded as major driving forces behind the recent changes in cotton production systems. The cotton industry went through the characteristic sequence leading from subsistence farming to a disaster phase, because of increasing reliance on chemical pesticides. Integration of biophysical and socio-economic aspects of cotton production allows for this evolutionary path and the obstacles to the dissemination of IPM principles among key stakeholders to be explained. Suggestions are made to facilitate the process of collective learning toward more sustainable IPM practices. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Systems approach; Cotton; Crop protection; Pesticide policy; Integrated pest management; Thailand

1. Introduction

Cotton production occupies a unique place in the field of pest control. Several examples in the world show that cotton production follows the classical 'pesticide treadmill', in which heavy reliance on synthetic pesticides works well for several years, and then proves disastrous. Without some form of integrated pest management (IPM), an entire region's cotton production may collapse, as happened twice in Thailand (Deema et al., 1974; Castella, 1996) and in other parts of the world (Barducci, 1973; Hearn, 1975; Eveleens, 1983; Matthews, 1989). Alternative IPM techniques that address problems of pesticide reliance have been successfully tested (Smith, 1969; Gips, 1987). Their relevance is now widely acknowledged by the scientific community and farmers have been

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informed of the availability of these techniques through extension services. However, there is a discrepancy between IPM promises and its effect because of slow or non-adoption by farmers (Eveleens, 1983; Evenson, 1987; Castella et al., 1995).

Early analysis of agricultural development in Thailand assumed that an increase in cotton production from small-scale farmers could be achieved through a more efficient use of existing resources and technologies, implicitly admitting that small farmers are technologically backward, lack entrepreneurship, and have limited aspirations. It was a result of the then widely accepted idea that technology was or should be developed by research centres, and then transferred to farmers, who, in turn, would adopt it. At that time techniques were isolated from the farm context, and they were mainly studied on research stations and evaluated at the plot level. Only biophysical considerations were taken into consideration.

An alternative view, pioneered by Schultz (1964), argued that farmers involved in traditional agriculture act rationally within the context of their available resources and socio-economic objectives. In other words, farmers are economically efficient but are confronted with techniques that fail to consider their priorities, constraints, and available resources. Farmers are not adopting techniques developed 'for them' in research centres, and any future adoption of a new technology depends on its building process. Therefore, the technological choices were considered within the framework of the whole farm. Agricultural research objectives and working practices were made to change, by analysing farmers' priorities and strategies, making on-farm experiments, and issuing specific recommendations to identified, homogeneous groups (CIMMYT, 1988). In parallel, economists used statistical tools to identify the diversity of farmers, programming techniques to model whole-farm planning, and study farmers' reluctance to adopt new technology. Sophistication also appeared in the analysis of the functioning of the farm, and its decision-making process, taking into account the influence of risk (Freund, 1956; Hazell and Norton, 1986; Holden et al., 1990). Sophistication about the relationships between the biophysical and the production systems appeared with the introduction of bioeconomic models (Haith et al., 1987; Reichelderfer and Bender, 1979; Swinton and King, 1994).

This type of research, however, tends to isolate the farmer, and to study him/her as an independent entity within a system. Once the production system is understood, its reaction to outside change is anticipated. This approach fails to consider the interactions between farmers, and, as it is now admitted that agricultural activities have several external effects, the interactions of farmers with other systems. Thus, a holistic approach is needed which considers a third system: the socio-economic one (Fig. 1).

This new system comprises all stakeholders or operators involved, their specific and often contradictory interests, their activities and interactions. When studying the introduction of IPM, there is a need to consider the three systems, and their interactions at different levels of analysis, time providing a third dimension to this study.

This paper attempts to apply such an approach to cotton production issues in Thailand. The objective was to understand better the process which led to misuses of chemical pesticides. A people-centred approach emphasises the relationships among the different stakeholders and pinpoints the diversity of their interests and related logics concerning pest and crop management. A comprehensive analysis of the reasons for farmers' reluctance to adopt IPM practices contributes to elucidate conflicting interests and may provide directions to encourage the development of sustainable cotton production systems in Thailand.

2. Methodology

2.1. *General methodological framework*

Four years (from 1991 to 1994) of interdisciplinary field work involving entomologists, agronomists, economists, social scientists, extension agents, etc. focused on the understanding of farmers' cotton management practices in two contrasting agro-ecosystems of the rainfed agricultural area at the periphery of the Central Plain of Thailand, in Kanchanaburi and Lop Buri provinces. The whole methodology developed by the DORAS (Development-Oriented Research on Agrarian Systems) project is reported elsewhere (Trébuil and Dufumier, 1993; Trébuil et al., 1994). Four keywords best summarise the main features of this

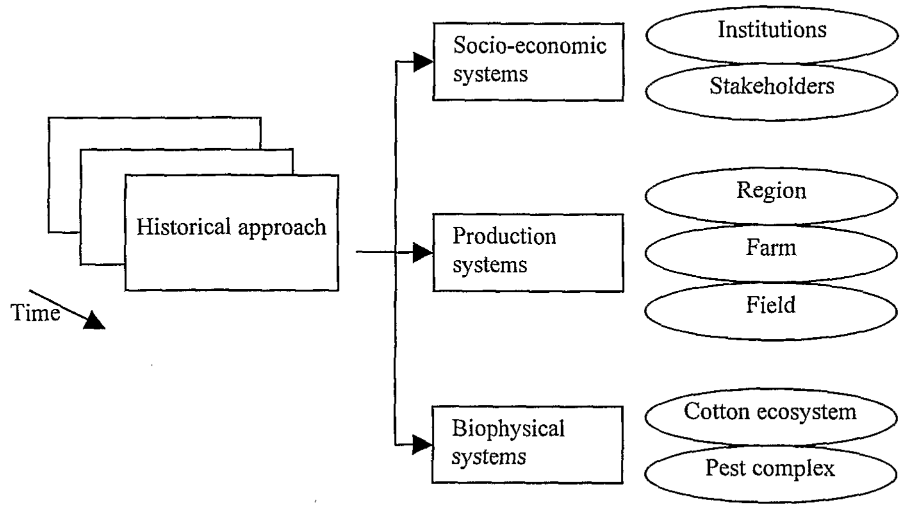

Fig. 1. Structure of the interdisciplinary research approach.

approach: systems oriented, dynamic, comparative, and interdisciplinary. It assumes that the existing situation of the agricultural sector is a social and historical construct. The analysis of the biological, social and economic sub-components of cotton systems at field, farm and regional levels explains the genesis and present status of current diverse on-farm circumstances. The study is characterised by the close articulation between a decentralised 'bottom-up' approach (analysis of farming and cropping systems in their socio-economic context) with a 'top-down' analysis of the local implications of national agricultural or institutional policies. Four levels of data aggregation were considered from agricultural policies at national level to cotton-based cropping systems (at field level) through regional and farm levels. Field-level studies are not reported in this paper, as findings were published elsewhere (Castella, 1996), but they are used to support results and conclusions at higher levels of integration.

2.2. Data collection and analysis

At national and regional levels: Data were collected in both cotton growing areas through informal interviews with key witnesses of recent socio-economic transformations (old farmers, middlemen, monks, local officials, field staff of agribusiness companies, extension officers, etc.). Information concerning the date, origin, causes, extent and consequences of the main agricultural changes was cross-checked between informants, and was matched to secondary data available at national or regional scales such as maps, statistics, bibliographic references, etc. Data analysis focused on the interactions between agro-ecological and socio-economic transformations and their effects on farmers' crop protection practices (Castella et al., 1995). A pesticide policy study as well as an institutional analysis of agricultural changes were conducted at the national level in order to complete the information already gathered at regional level.

At the farm level: The farm sampling procedures aimed at maximising the diversity of farm circumstances and production strategies to be analysed. The selection of some 30 farms per research site was guided by the results of the regional study. Three-to-four farmer interviews were undertaken over one year (followed each time by a visit of the fields) and were sufficient to reveal the main features of each farming system (Capillon and Manichon, 1991).

Farming systems were categorised into different types according to the main orientation of the production unit and farmer's objectives along with the strategies implemented to reach them (Castella et al., 1995). The same criteria were used to classify a large descriptive sample of farming systems surveyed in the same two regions (823 farms in Lop Buri and 538 in Kanchanaburi). This second survey aimed at validating the farming systems' typologies based on their differentiated functioning and at evaluating the frequency of the different farm types.

Knowledge acquired through on-farm studies conducted at different integration levels was then synthesised, cross-checked, and compared with other sources of information: secondary data, literature, and DORAS project's on-farm and on-station experiments.

3. Results: history of cotton production and crop protection problems in Thailand

The history of the Thai cotton industry exemplifies the concept of a characteristic sequence of six phases of crop production in relation to pest control:

(1) subsistence phase;
(2) ecological phase;
(3) exploitation phase;
(4) crisis;
(5) disaster; and
(6) integrated control.

Smith (1969), Falcon and Smith (1973), Bottrell and Adkisson (1977) showed that elements of this pattern have been identified in cotton growing in various countries. The purpose in this section is to identify the succession of ecological, technical, and socio-economic events that affected Thai cotton production areas during the last 40 years and their effects on the current organisation of the cotton sector.

3.1. First rise and fall of the Thai cotton industry: from subsistence (1950) to disaster (1975).

3.1.1. The subsistence phase

Before the 1950s, cotton was traditionally grown in Thailand by subsistence farmers for their own needs (Grimble, 1971). National average annual production was ca. 8000 t of lint. Cotton yields were poor and pest control depended solely on natural control mechanisms; the pest resistance inherent to native varieties, hand-picking of pests, and other cultural practices. Native Asiatic cottons (*Gossypium arboreum*) were progressively replaced by Cambodian cottons (*G. hirsutum*) of better fibre quality, but total output remained at a low level until the mid-1950s.

3.1.2. The ecological phase

From that time onwards, two main factors stimulated cotton production: the rapid increase in domestic raw cotton consumption because of the expansion of textile industry, and the opening up of new agricultural areas in forested uplands at the periphery of the Central Plain. The improvement in the control of malaria and the construction of all-weather roads increased the attraction of potential settlers from the lowlands, pushed away by population pressure and consequent land shortage. The double objective of this policy was to increase and diversify agricultural production for exports (that previously relied almost exclusively on rice and rubber), and to pacify forested areas, considered at that time as a refuge for brigands and political opponents (Silcock, 1970).

The first wave of settlers cleared manually a degraded secondary forest or bush already exploited by timber companies, charcoal-burners or slash-and-burn cultivators. Agricultural production, aiming at self sufficiency, consisted predominantly of upland rice and traditional vegetables. Improved access to markets and the changing price ratio of rice and other upland crops, in favour of the latter, encouraged farmers to adopt upland cash crops. A local trade, developed by mostly Sino-Thai merchants, consisted in the exchange of basic household consumption goods (such as rice, lamp petrol, etc.) for agricultural products. Rapidly, these middlemen became the only farmers' linkage with more developed lowland regions.

The composition of the cotton insect pest complex evolved with the extension of forest clearing and rapid spreading of the maize–cotton relay cropping systems. Subsequent uniformity of land cover led to outbreaks of the Bombay locust (*Patanga succincta* L.) in the central uplands area. By the late 1950s, farmers faced heavy crop losses caused by locust pests (Jalavicharana, 1969). Massive DDT aerial sprays were conducted by government institutions (Department of Agriculture (DOA)). Meanwhile, malaria eradication programmes applied the same techniques against mosquitoes over vast areas. However, up to the early 1960s, farmers themselves did not use pesticides and relied exclusively on cropping practices, biological control and host-plant resistance (e.g. selection of cotton cultivars tolerant to jassids (*Amrasca biguttula* Ishida), bacterial blight and leaf-roll virus) to control pests.

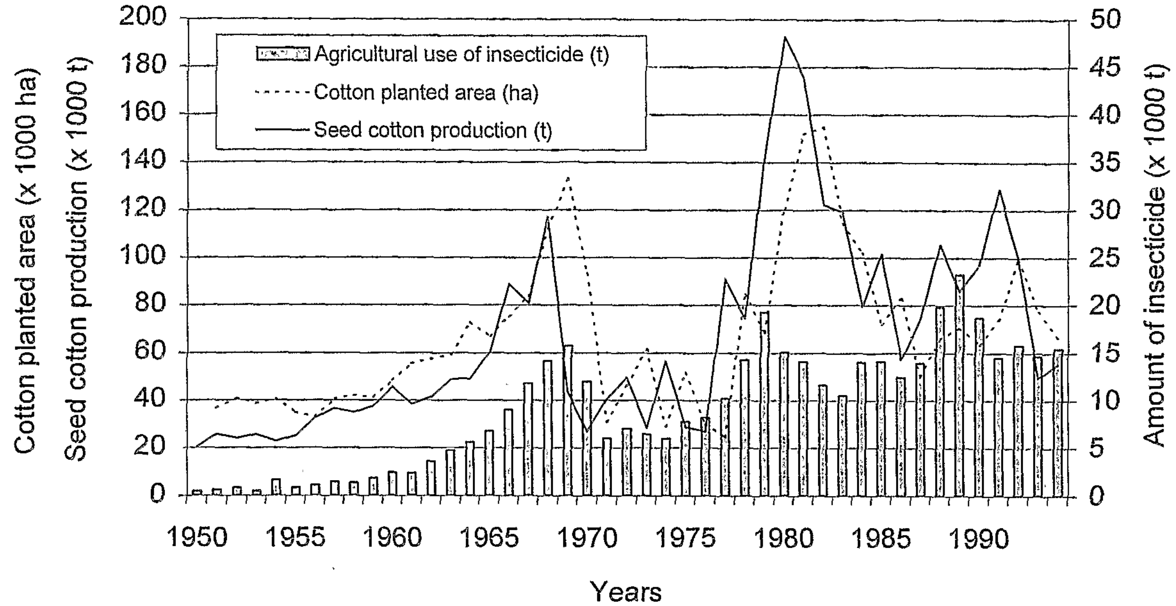

Fig. 2. Evolution of cotton production and agricultural use of insecticides in Thailand from 1950 to 1994.
Source: Office of Agricultural Economics and Division of Poisonous Articles, Ministry of Agriculture and Cooperatives.

3.1.3. The exploitation phase

Introduction of farm tractors in the early 1970s allowed double cropping of the heavy upland soils. Mechanisation of clearing and land preparation was actively promoted by the village middlemen, even in remote areas. Up to 1968, the expansion of cotton production was area-based rather than yield-based (Fig. 2).

Considerable efforts were made towards screening and breeding new cultivars producing both, higher yields and better quality lint. At the end of the 1960s, dissemination of introduced types such as 'Stoneville-2B' and 'Deltapine Smooth Leave' cultivars encouraged cotton growing so that production rose to a peak of 117 000 t of seed-cotton in 1968 (Fig. 2). These cultivars presented characters of tolerance to bacterial blight but their glabrous leaves made them highly susceptible to jassids (Fig. 3). Insecticide use was then necessary for these cultivars to express their potential yield (Wangboonkhong, 1981). Up to the mid 1980s, the evolution of insecticide use in Thai agriculture was intimately linked with the expansion of cotton production (Fig. 2), as most pesticides sprayed on cotton were imported (Deema et al., 1974).

The new organochlorine insecticides were so efficient that farmers used them on a season-long, calendar preventive-treatment schedule, as a reliable form of crop insurance for a high-risk investment. The pest complex evolved with the characteristics of cotton cultivars, the nature of insecticides applied by cotton growers and spraying intensity (Figs. 3 and 4). Insects considered as minor pests gradually became major constraints to cotton production (Deema et al., 1974). In the 1962–1963 season, three insects – spiny bollworm (*Earias vittella* F.), pink bollworm (*Pectinophora gossypiella* S.) and jassid – were classified as 'very serious' pests (Anthony and Jones, 1963), but only the jassid remained of serious importance afterwards. The jassid, however, was easily controlled, whereas cotton bollworm (*Helicoverpa armigera* Hubner) became a far greater problem (Castella, 1996).

3.1.4. The phase of crisis

A fivefold increase in *Helicoverpa* resistance to organocholorine formulations was recorded over the 1970–1973 period (Deema et al., 1974). The development of DDT and endrin-resistant strains of *Helicoverpa* was the result of an indiscriminate use of

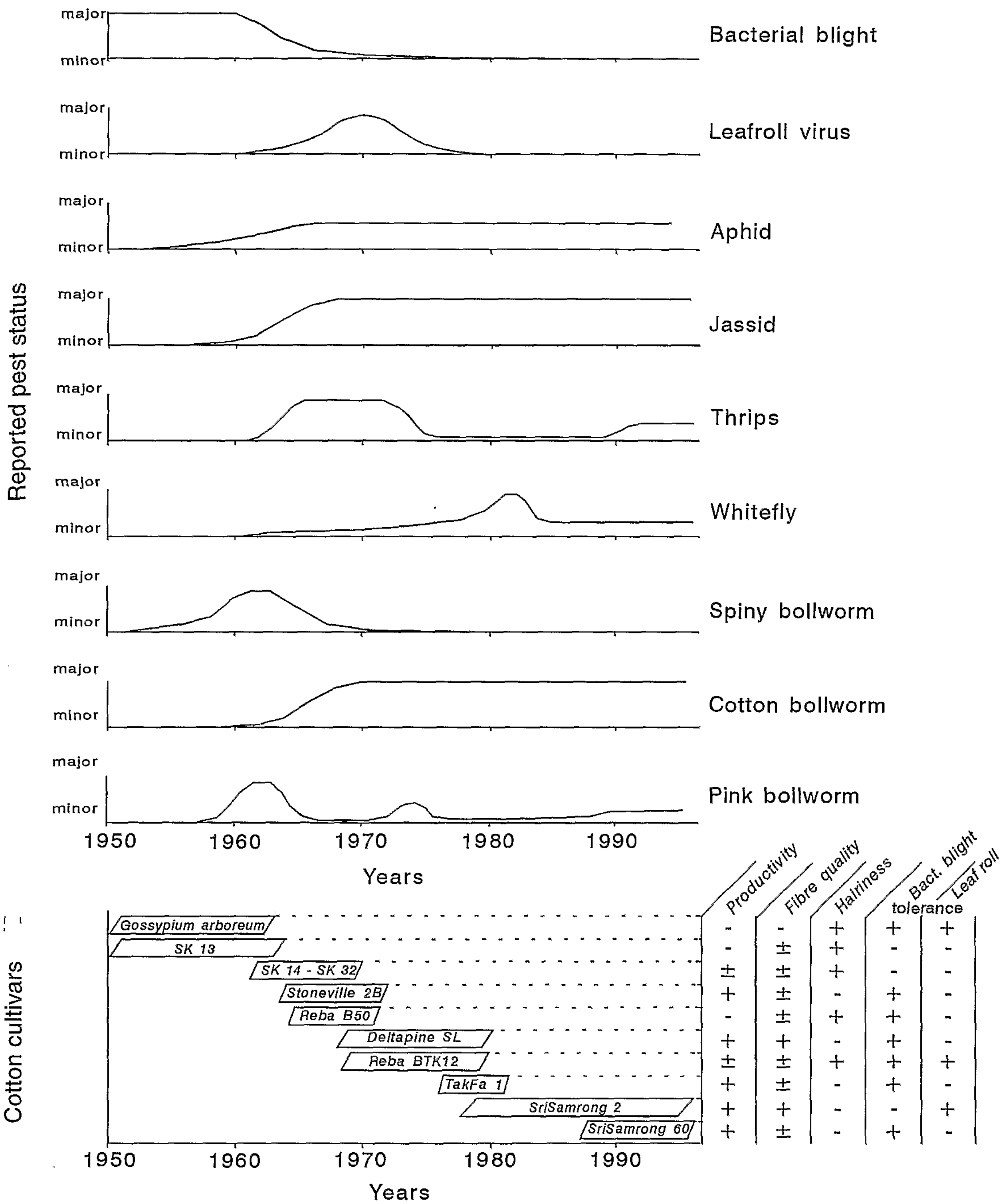

Fig. 3. Temporal profile of cotton pest complex in Thailand with respect to the evolution of cultivar characteristics: (+) high; (±) medium; and (−) poor.

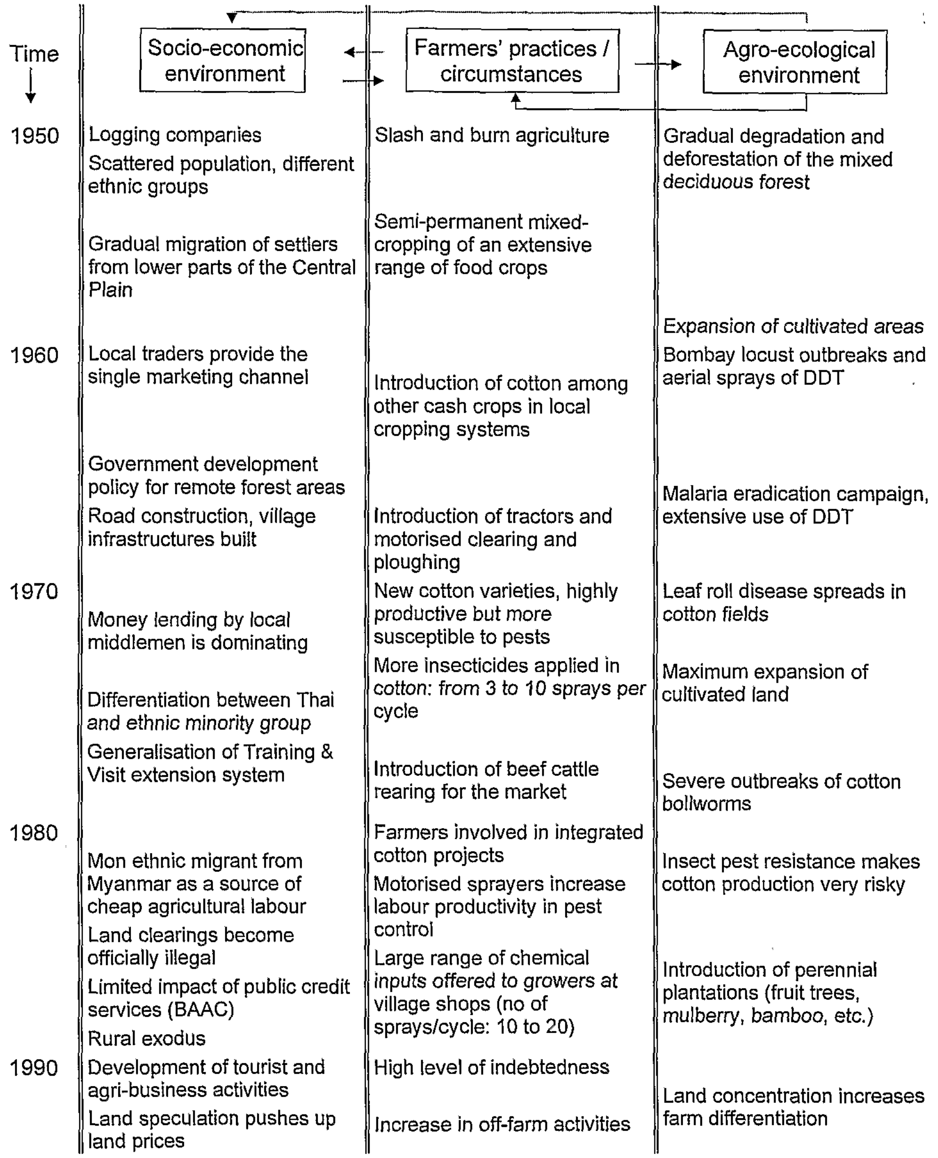

Fig. 4. General historical profile of main changes in the Thai cotton sector since 1950.

insecticide mixtures, the increase of cotton cropping both, in time and space within a few years, as well as the association of cotton with maize, an alternative host for *Helicoverpa*.

Methyl-parathion and gusathion, two organophosphorous compounds, came to the rescue and were added to toxaphene – DDT formulations. Although these cocktails were highly effective at first – they also killed beneficial insects – triggering outbreaks of secondary pests, and leading to the development of 'super *Helicoverpa* strains' resistant to both, organochlorine and organophosphorous insecticides. Increasing amounts of insecticides were applied at increasingly shorter intervals (Figs. 2 and 4). Farmers were trapped in an endless treadmill of chemical treatments. Cotton production became non-profitable, and serious insecticide poisoning persuaded most farmers to stop growing this crop. Farmers switched

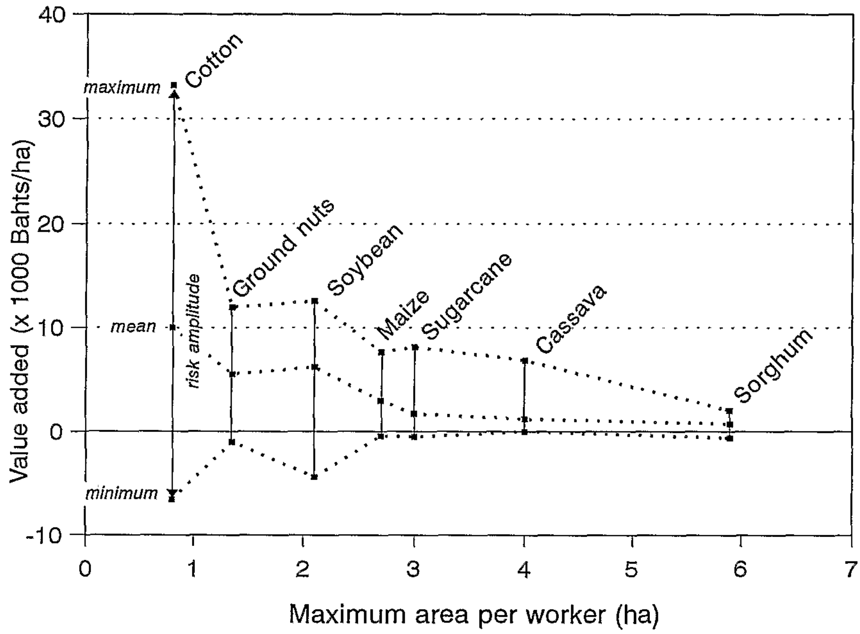

Fig. 5. Comparison of productivity, economic risk and labour requirement for the crops commonly grown in rainfed agricultural areas of Thailand (period 1992–1994).
Source: On-farm surveys in Chaibadan district, Lop Buri province, over a representative sample of 823 farms.

to other crops requiring less inputs, particularly cereals (maize, sorghum) and grain legumes (soyabean, mungbean and groundnuts). Most of these alternative crops had low returns per hectare, but proved to be less risky and required substantially less labour input (Fig. 5). At the same time, the drop in acreage under cotton in what had become the established areas for this crop was in part buffered by the continuous spread of new pioneer fronts in remaining forest areas and agricultural margins (Fig. 6). The attraction of opening such new land to cotton was that insects did not, for the first year or two, present a serious problem. The sequence of increasing crop protection problems was then moved from place to place allowing some stabilisation of national production around 40 000 t of seed cotton up to the end of the 1970s.

3.1.5. The phase of disaster

Instead of reinforcing the cohesion between stakeholders of cotton sub-sector, the pest-control crisis revealed conflicting strategies among them.

Government policy: As cotton production could not keep pace with the rising industrial demand for lint (Fig. 7), government policy was torn between two opposing goals. On the one hand, it had to support domestic production in order to maintain a relative independence of the textile industry from raw material imports. Cotton prices were kept high on the domestic market as an incentive for farmers to grow cotton. However, pest-control problems pushed up production costs and economic risks for growers, leading a lot of them to give up cotton growing. On the other hand, facing a shortage on the domestic market, the government was forced to favour cotton imports through low import duty in order to support the rapid expansion of the textile industry. Imported cotton was subject to an import duty of Baht 0.33 kg^{-1} (about 2–3% of the Bangkok price of lint), when cotton yarn and cotton fabrics were subject to import duties of 25 and 40%, respectively. This fiscal policy protected the domestic market for processed textile products and allowed the import of raw cotton at low cost from the world market. It further decreased the competitiveness of domestic cotton and hampered a possible revival of Thai cotton production.

Ginning factories: The number of privately owned cotton ginneries in Thailand increased rapidly in the 1960s to take advantage of the expanding cotton

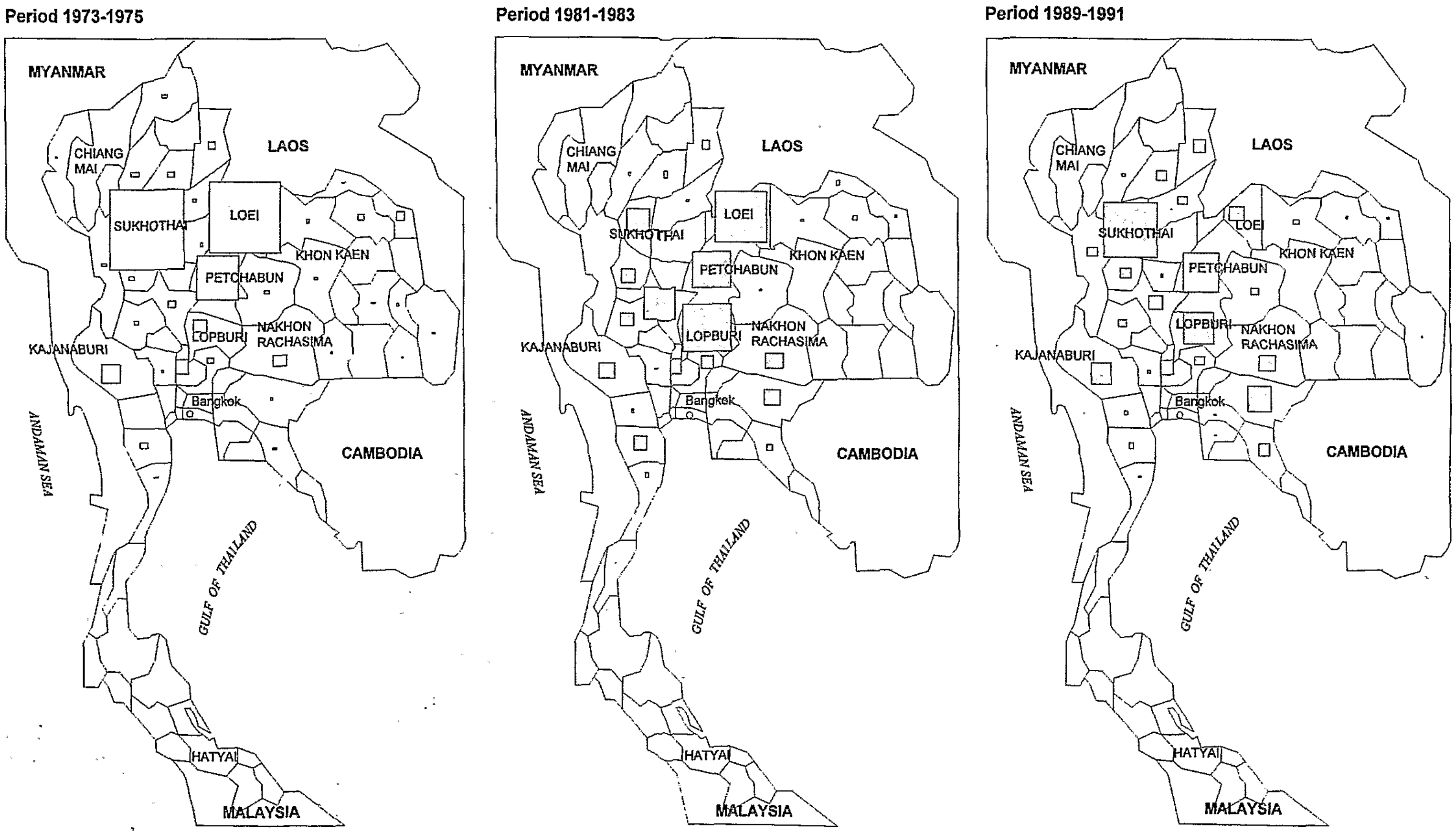

Fig. 6. Distribution of cotton areas among provinces. Square size is proportional to the contribution of each province to national production. Average annual seed cotton production for the three three-year periods 1973–1975, 1981–1983 and 1989–1991 is 38, 139, and 104 thousand tons respectively.
Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

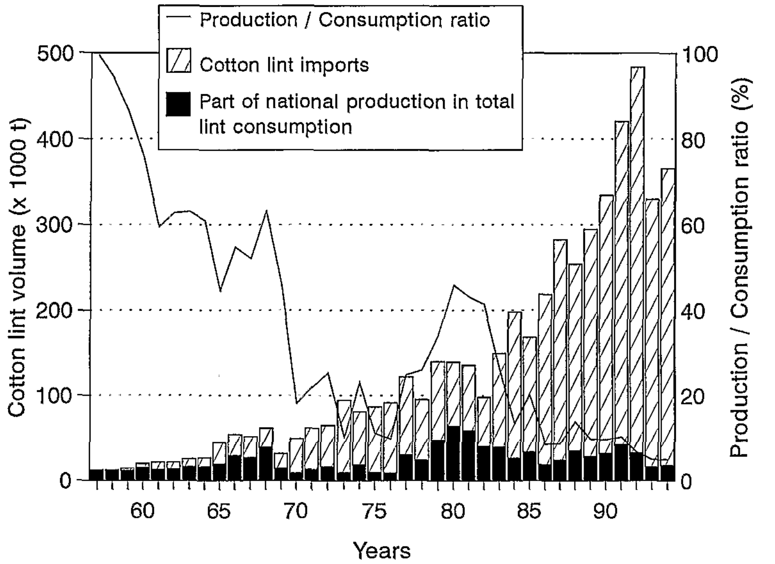

Fig. 7. Evolution of domestic cotton lint production and consumption by the Thai textile industry.
Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives and the Division of Textile Industry, Ministry of Industry.

production. By 1970, there was a total of 86 small capacity ginneries, mainly scattered across central Thailand. A combination of lack of information available to prospective ginnery owners concerning the country's present and predicted ginning capacities, and the sudden contraction in the cultivation of cotton resulted in considerable excess ginning capacity and poorly located plants (Grimble, 1971). As a result of the setback in cotton production, most ginneries worked on very low throughputs or even closed down. The shortage of cotton at ginnery level had two important effects. Firstly, in the ginner's attempt to maximise throughput, there was intensive 'bidding up' in the seed-cotton price paid to the farmer. Secondly, for similar reasons, ginners paid little attention to the quality of the seed cotton purchased and to that of the ginning process itself. The ginneries worked on such low margins that they cut production costs to a minimum; worn out gin parts were not renewed, supervision was minimised, etc. and the grade of lint suffered as a consequence. Ginneries could not pass the higher price of the raw material to the textile mills because competition amongst themselves and from imported cotton restricted their bargaining power (Grimble, 1971). As a consequence, there was little, if any, price increment at farm level for quality seed cotton and, therefore, little incentive to improve it. Poor quality cotton lowered the relative advantage of domestic production over imports.

Agrochemical companies: Up to 1974, most of the insecticides were imported. Facing a sharp reduction in insecticide use because of the disaffection of growers for cotton, multinational companies invested in insecticide formulation and packaging plants. Imported compounds were formulated locally, lowering production costs and reducing insecticide prices and maintaining profit margins. A competition started among local and international companies, between imported and local formulations, that is still going on (Assouline, 1988). Formulation quality suffered from the struggle for shares of a reduced market. More than 20% of pesticide samples analysed by the DOA (1973) were found to be deficient in active ingredient, have contents other than specified on the label, or contained poor quality emulsifying agents (Deema et al., 1974). This figure reached 44% in 1983 (Tayaputch, 1992). Marketing was essentially directed towards private retailers, middlemen as well as government agencies in charge of pest control (malaria eradication programmes, locust control and agricultural extension services).

Research and extension agencies: The cotton crisis caused a shift in DOA's research topics, from essentially breeding programmes (improvement of yield and fibre quality, host-plant resistance) to entomological activities. The disaster phase marked a new change, from a mere screening of active ingredients against various cotton pests to integrated crop protection (Wangboonkhong, 1981). DOA entomologists, supported by foreign agencies, demonstrated the technical and economic relevance of cotton IPM in Thailand (Deema et al., 1974). However, the slow rate of increase in yield per ha was disappointing when compared with the considerable development in agronomic knowledge and the selection of improved cultivars brought about by the DOA's research and experimentation programme (Grimble, 1971). Research efforts confronted three major constraints that considerably limited their development and the scope of their application.

(a) Different research methods and technology packages were 'imported' from outside (USA, Africa, etc.), to be tested and adapted to Thai cotton production. Technical innovations were proposed, together with each new cultivar to adjust it to its new environment. However, criteria for introduction of a new cultivar were based on its superiority over previous ones in terms of potential yield and fibre quality. High cultivar susceptibility to a pest complex, different to its country of origin, was managed by large spectrum insecticides.

(b) Research efforts and funding were restricted to the years of booming cotton production; thereafter, researchers, just like farmers, turned to other crops easier to deal with.

(c) Top-down development models being the rule, research topics were driven by purely technical questions not related to local on-farm circumstances. Researchers did not cooperate with farmers, and extension agents were blamed for not reporting growers problems to research agencies. In 1977, the Department of Agricultural Extension (DOAE) adopted the Training and Visit (T&V) system promoted by the World Bank (Benor and Baxter, 1984). Nation-wide introduction of T&V was considered a solution to communication problems between researchers and farmers. An extension agent in every sub-district was in charge of transferring technical innovations from research stations to farmers through regular visits. Under this system, extension agents (EA) were kept abreast of the latest research findings and of appropriate technologies in farming on a fortnightly basis. The adoption of T&V system corresponded to the need for closer relationships with farmers, the village middlemen being their only previous source of technical information (Phongprapai and Setty, 1988).

Farmers and middlemen: Even when based on proper information, farmers were not free in their technical choice. In the remote rural areas, where most of cotton production was located, there were frequently limited supplies and number of dealers. Growers could not respond to the increasing complexity of the pest problem by adapting their pest management techniques. A high percentage of pesticides used by farmers were bought locally, on credit. Under exclusivity contracts, farmers had no choice either in the inputs used or in the place and price for their seed cotton sales. Middlemen controlled all the steps of the production process and were the only link between farmers and other stakeholders of the cotton industry. They developed commercial relationships with small farmers by providing them with a complete range of services: from equipment (tractor ploughing, maize ginning, etc.) to seasonal credit (for inputs or hired labour force), marketing of products, technical advice, and social services. They were interested in maximising the inputs lent to their clients at high interest rates (3–5% per month), and in maximising harvests that they could buy at a low price. They had thus no particular interest in promoting integrated pest control practices.

3.2. Repetition of the sequence: from exploitation (1975) to the current crisis

3.2.1. Exploitation again

By the late 1970s, pyrethroid insecticides provided a highly efficient protection against cotton bollworm populations, most of which had become resistant to the previous generation of insecticides. Pyrethroids had a low human toxicity, were highly effective against *H. armigera* and relatively cheap (because of their low dosage rate), and farmers generally used them during the entire season (Wangboonkhong, 1981). As a consequence, cotton cultivation spread rapidly over entire regions again, especially in the rainfed cotton area and along the last pioneer fronts, close to border regions with Myanmar to the west and Cambodia to the east (Fig. 6). Cotton disappeared, however, from newly irrigated areas of the Central Plain as increased crop-protection problems reduced the benefit of irrigation. The average area planted per grower increased from <1 ha to 4–5 ha. Within three years, cotton production boosted to an all-time record of 192 000 t of seed cotton in 1981. All ginneries reopened and new ones settled. Government policy favoured national cotton production through low import duties for pesticides (5%) compared with mineral fertilizers (30%) and agricultural machinery (20%). This indirect support to the pesticide sector caused major changes in the agrochemical industry. The number of local companies increased rapidly to take advantage of this favourable legislation. From rather slack relationships with farmers, agrochemical firms became familiar with cotton growers via active local representatives who trumpeted their technical advice up to the most remote villages. All kinds of marketing techniques were used, such as free pesticide samples, demonstration plots, etc., to attract the attention of growers. Gifts such as travel grants or commissions contributed to bind clients from almost all stakeholder groups involved in the agricultural sector. Farmers spent more and more on insecticides, increasing considerably production costs and becoming increasingly dependent on village middlemen.

3.2.2. Crisis phase again

The intensification of the production system encouraged by the technical innovations and government incentives (public support to integrated cotton projects, extension services, credit institutions, etc.) again came to a standstill because of insect pest resistance. After three years of intensive use of pyrethroids, *H. armigera* populations could not be controlled any more, and whitefly (*Bemisia tabaci* Gennadius) emerged as a secondary pest. Farmers throughout the country complained about the lack of effectiveness of insecticides. This was supported experimentally by data from field trials as well as laboratory analysis (Collins, 1986; Sinchaisri, 1988). Insecticide resistance was also noticed in other major pests such as aphids (*Aphis gossypii* Glover) and jassids (Ouchaichon, 1986). Numerous cases of insecticide poisoning were recorded (Wongphanich et al., 1985; Ministry of Public Health, 1994).

Farmers could not shift any more to areas free of insect resistance to reproduce the insecticide-intensive model of cotton cultivation. By the early 1980s, regional shifts in cotton cultivation had explored all land available and the pioneer front had reached marginal areas less suitable to cotton growing.

3.2.3. Disaster phase again

Research and extension agencies: IPM was again promoted by local scientists. However, as in the previous cycle, crop protection problems exacerbated inter-institutional tensions instead of reinforcing coordination between agricultural services. For example, researchers and extensionists disagreed on the technical solution to catastrophic crop losses from viral leaf-roll disease transmitted by aphids. Each party tried to demonstrate the relevance of its position and they finally divided cotton areas into two zones, where each institution tested its own solution.

The lack of co-ordination between research and extension services was one of the major reasons for the information gap between farmers and governmental agencies. Phongprapai and Setty (1988) detected shortcomings of the T&V system that were to be confirmed by the present on-farm surveys. Despite a good knowledge of local agriculture and relationships with farmers, extension agents (EA) failed to convince farmers on different technical topics. The latter believed that EA lacked appropriate technical knowledge and experience. On the other hand, EA complained that the poor training programme provided to them was hardly relevant to the farmers' real problems. A heavy administrative work load and the sophisticated agricultural knowledge expected from them on a broad range of crops often led EA to focus on crops easier to manage. Consequently, cotton protection often received less attention. In recent years, extension activities in the field of cotton protection were restricted to the publication of a leaflet ranking insecticide brand names according to quality criteria, along with recommended doses for application. Unfortunately, these efforts often remained useless, farmers attention being constantly attracted to new insecticide brands (often of doubtful quality) heavily advertised by local middlemen and agrochemical companies. Among other incentives to cotton production, extension agencies provide free seeds as well as small amounts of insecticides to growers. However, in recent years, seed quality was questioned (problems of contamination and low germination rate) as well as the relevance of free insecticide distribution in a programme aimed at decreasing farmers' reliance on pesticides.

In the absence of a convincing technical solution to cotton growers' problems, other culprits had to be found. Middlemen were accused of overloading farmers with debts and delivering doubtful technical information in order to maximise their profits. DOA and DOAE co-operated against a common enemy: the village middleman.

Integrated cotton production projects were set up to counteract local middlemen influence over small farmers. Direct links were established between growers and other stakeholders. Groups of cotton growers were set up, which could have access to bank credit under a mutual responsibility system, and to technical advice from local DOAE agents. Inputs were provided through contracts with agrochemical companies, and guaranteed seed cotton prices were negotiated with ginners (Trivithayacun, 1980). However, extension agents gradually substituted themselves for middlemen, as their role as input suppliers took over that of technical adviser. Farmers' decreasing interest was reinforced by the lack of flexibility of these projects and administrative worries (Kusakabe and Higuchi, 1992). This system collapsed after several bad cotton cropping seasons, as group members failed to reimburse their loans.

Ginners: Despite its failure in reducing middlemen key position, the experience of integrated cotton production projects succeeded in building new relationships among stakeholders. In an attempt to control cotton production volume and quality at the farm level, some of the ginners created their own integrated cotton production projects. They responded to a new decrease in cotton quality by establishing private contracts with farmers and providing their own extension agents. In fact, the pest management crisis pushed farmers to grow native cotton cultivars more tolerant to pests in an attempt to reduce pest damages. Seed cotton of these low fibre quality cultivars was often mixed with the good quality one and thus lowered the grade of the whole production. The solution developed by ginners to avoid the problem was to monitor farmers fields from sowing to harvest. However, such 'integrated projects' were affected by the high cost of extension agents against the slim margin offered by the ginning process. Companies overcame the problem by selling inputs on credit and through the production of certified cotton seeds. These activities today provide the greatest part of the profits and the local representatives have shifted gradually from a role of extension agents to that of merchants.

Middlemen: Despite the general cotton crisis, local middlemen retained a considerable influence over the cotton industry, as with other agricultural products. They kept growing cotton despite high levels of insect pest resistance by transferring the risk to other people of lower social status. In border areas, such as in Kanchanaburi province, the drawback of cotton production led middlemen to enrol illegal immigrants from Myanmar to grow cotton and to substitute for Thai farmers abandonment of this crop. People from the Mon ethnic group, illiterate in the Thai language, put themselves under the protection of local middlemen to avoid being expelled over the border. As a price for this protection, they have to practice a maize–cotton relay cropping system on plots of land provided by the local middlemen. The village merchants open an account per family at the beginning of the cropping season, where all purchases (for inputs or consumption goods) are registered and bear a flat 5% interest per month. At harvest time, farmers get the difference between the gross product and the total of their expenses. Nowadays, most of the seed cotton in Kanchanaburi area (i.e. ≈80% of the total cotton area in this particular province) is produced through this system. However, these 'illegal' growers are not registered by agricultural services and, consequently, do not appear in official statistics. But agrochemical companies know them well and advertise pesticides in the Myanmar language in this area.

Agrochemical companies: Two categories of producers/distributors are active in Thailand. The first group is made up of 'national' distributors, that are not linked to a particular, international group. The second group comprises a few national subsidiaries of international groups, which control an important market share. Insecticides are usually imported as technical products to be formulated locally, or directly as formulated products for the most sophisticated ones for which repackaging only is taking place in Thailand.

The first group formulates and distributes commercial products on a large scale and at low cost, given the not-too-stringent national legislation. These firms are very active and distribute large-spectrum, low-price insecticides. Their number increased rapidly in the 1980s to take advantage of the demand for insecticides, when international companies concentrated on new high-technology products such as pyrethroids. Their strategy is to find large markets, and to limit as much as possible, via their national association, any modification in the legislation that could jeopardise their positions. The second group distributes a complete range of pesticides, and as such, has the most ambiguous attitude. On the one hand, these companies develop new pesticides, intended to have little negative effect on the users and the environment, for sophisticated markets, e.g. USA, Europe and Japan, and only marginally for developing countries. On the other hand, they compete in emerging markets such as Thailand with the first group of producers. Because they have an international reputation to preserve, they are promoting new concepts, such as that of 'IPM-compatible pesticides'. They are lobbying actively for changes in the national legislation that could eliminate the first group of companies from the market. However, being realistic about the likelihood of such a change in the short term, they also continue to compete with the first group, using similar strategies and products.

One of the strategies developed by small firms to cope with the reduction of insecticide efficiency consisted in creating new commercial products by simply changing their trade names or the formulation of the active ingredients. Monocrotophos is a striking example that was distributed in Thailand under more than 300 trade names in 1995! The competition among agrochemical firms has resulted in an inflation of the number of registered pesticides. As of 1995, over 3600 pesticides were legally registered in Thailand (ESCAP, 1996).

A direct consequence of this large number of products available is farmers' confusion when using insecticides. Firms are suspected of deliberately maintaining such a confusion in order to secure their market share. The regulatory body has no power to limit the number of pesticides, because any repacker of pesticides, regardless of its size, is considered as a producer in Thailand, and is entitled to apply for a registration permit. Besides, some unregistered pesticides are also being distributed by unregistered companies (beyond any kind of control), adding to the already confusing situation (Grandstaff, 1992). As a result of the weaknesses of the Thai pesticide policy, which left ample room for private initiatives (Waibel, 1990; Jungbluth, 1996; Ishii-Eiteman, 1995), the private sector has taken over the dissemination of technical packages and the organisation of the cotton industry.

4. Discussion: learning from past experiences

The history of the Thai cotton industry shows how the current, complex pest management situation developed. The following section aims at disentangling the interactions between ecological, technical and socio-economic components of the cotton production system, which led to the collapse of cotton industry (Fig. 4).

4.1. Agro-ecological aspects

The same scenario repeated itself all around Thai cotton producing area (Fig. 8):

- a continuous simplification of the ecosystem, through forest clearing and rapid expansion of a few crops (mainly maize and cotton), and
- a steady decrease in the entomofauna diversity because of the uniformity of the cultivated ecosystem and intensive use of chemical insecticides.

It resulted in high levels of insect resistance, economic risk, environmental and health hazards, and with most farmers stopping cotton growing in the main production areas.

As with the previous disaster phase, farmers and other stakeholders of the cotton industry still believe in a major technological innovation that will get them out of the pest management crisis. Loyal to the paradigm of linear technical progress, they now expect biotechnologies to provide the ingredients of a new revolution in cotton protection. However, as suggested by observations in the USA (Rajnchapel-Messa, 1993; Rissler, 1997), the release of genetically transformed *Bt*-cotton could initiate the beginning of a new cycle from exploitation to disaster. As for the previous generations of crop protection technologies, a poor management of insect resistance may wipe out the benefit of many years of research within a few cropping seasons.

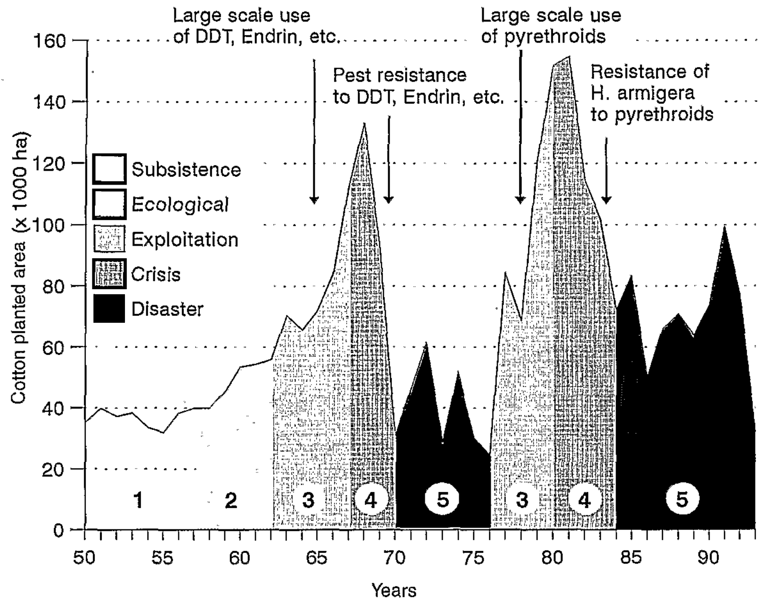

Fig. 8. Changes in areas planted to cotton in relation to the successive phases in cotton crop protection in Thailand. (1) *Subsistence phase*: traditional cultivars highly tolerant to pests and diseases. (2) *Ecological phase*: introduction of new cultivars with higher productivity and fibre quality but more susceptible to pests and diseases. Breeding for varietal tolerance to pests. (3) *Exploitation phase*: high productivity, thanks to chemical inputs (fertilizers, insecticides, etc.) (4) *Crisis*: insect pest resistance to pesticides; heavy damage difficult to control. (5) *Stabilisation phase after a disaster*: decrease in number of cotton growers, promotion of IPM principles.

4.2. Socio-economic aspects

Sustainable IPM means more than technological innovation. Its implementation requires that agro-ecological principles be translated into a socio-economic framework, respecting farmers objectives (Teng and Savary, 1992). The example of Australia shows that the cotton industry could recover after a disaster phase, thanks to a strong coordination between stakeholders (Cox and Forrester, 1992), who contributed together to manage insect pest resistance.

In Thailand, even if farmers' attitude towards IPM is generally positive, increasing risks of pest damage tend to push cotton growers into trying to develop their own crop management strategies. Instead of tackling the pest problems at the roots through community management, they have always avoided facing the problem by developing individualistic strategies.

Avoidance and individualism are the keywords that best describe the profound causes of the cotton crisis in Thailand. Stakeholders never engaged in a problem-solving process, as long as other alternatives were available. The cotton industry's response to the first collapse was a geographic expansion of cotton systems through growers migration. The second disaster was counteracted by crop diversification, the development of off-farm activities or the transfer of risk to other people. These alternatives were easier to implement as individual decisions alone were required.

The network of social relations linking cotton stakeholders (Fig. 9) became evermore complex with time in parallel with the agro-ecological sequence presented above (Fig. 8). Crop protection problems triggered the emergence of different, and often conflicting, strategies among stakeholders depending on their objectives, their position in the commodity chain and their relationships with growers. The successive transformations of the 'socio-economic configuration' led to a gradual adaptation to cotton shortages. With a domestic production covering <10% of the textile industry consumption (Fig. 7), it became convenient and less risky to develop a favourable import policy than a large scale IPM programme.

As a consequence, the cotton industry cannot be analysed as an organisation with one or several linked decision centres, implementation agencies, informa-

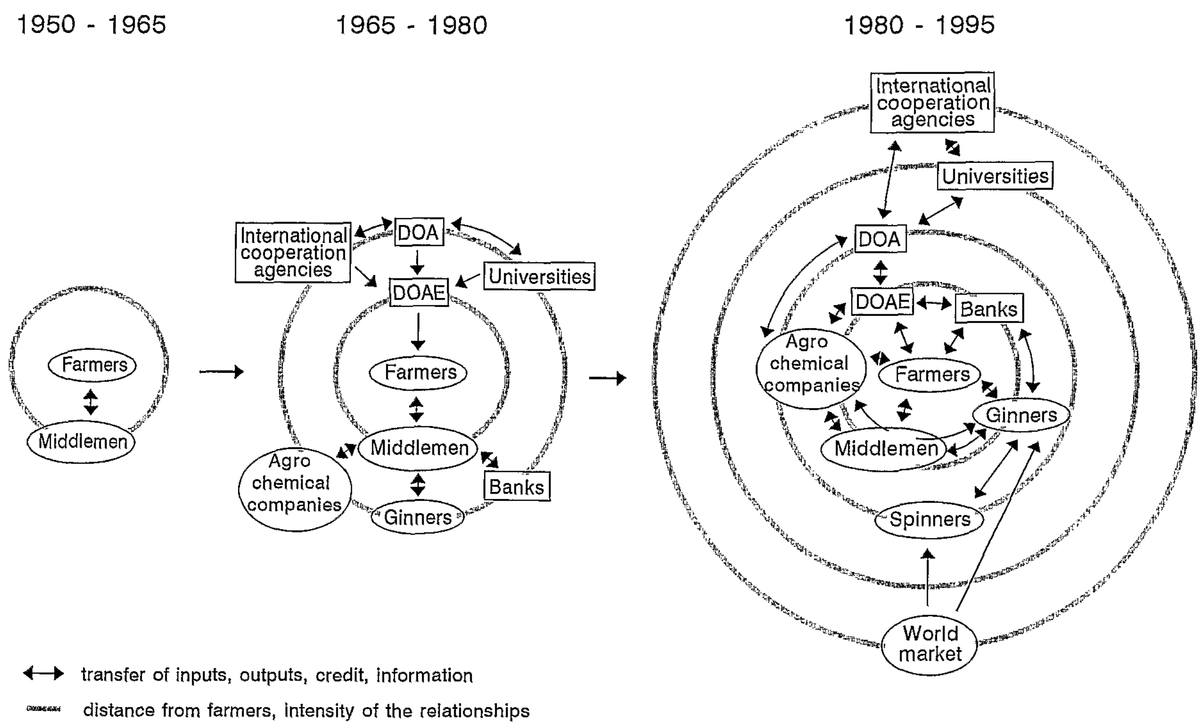

Fig. 9. Recombination of social relationships among the various stakeholders in the cotton industry. (DOA=Department of Agriculture; DOAE=Department of Agricultural Extension)

tion and regulation systems, etc. Instead, one has to deal with the emergent structure of aggregated individual behaviours and strategies. This network recomposes itself continuously, depending on forces and reactions that its components exert on one another. It is thus very difficult to anticipate the aggregative effect of the introduction of a technical innovation without prior knowledge of the complex social system that will handle it. Furthermore, the lack of a clear leadership in the industry makes it difficult to control, regulate or enforce the implementation of any decision.

5. Conclusions: towards IPM facilitation

The diffuse nature of Thai cotton sector makes it difficult to identify the responsibilities in the disaster. Farmers cannot be confined to the role of ignorant, risk-adverse or pesticide-addicted players. Local middlemen are much more than pesticide salesmen, burdening small farmers with debts. The same is true of extension workers, researchers, pesticide companies' representatives, whose strategies are not exclusively defined by their title, but by their position in a complex socio-economic network. The challenge for the Thai cotton industry now consists in changing the current socio-economic configuration into a new one compatible with the implementation of IPM principles.

To this end, three prerequisites should be fulfilled:

1. A new, favourable institutional and policy framework needs to emerge (Waibel, 1990).
2. IPM practices suiting the local, agro-ecological and socio-economic context of cotton production are required (Castella et al., 1995), using a system-oriented rather than single-commodity, or pest-oriented approach.
3. A coordination platform (Röling, 1994) should be adopted by all stakeholders aiming at an acceptable compromise between individual strategies and the common good.

The interdisciplinary approach presented in this paper looked at the cotton production system from the perspective of the major stakeholders. It is considered as a basis for the development of a negotiation support system that would act as a catalyst for major institutional changes, such as

(i) the recognition of the usefulness of drastic government measures in the field of pesticide policy;
(ii) the regulation of the cotton market;
(iii) the development of technical innovations fitting each main type of farmers' situations; and
(iv) the conception of concerted actions to manage the cotton-based ecosystems in a sustainable manner.

Such a tool would help stakeholders to simultaneously learn their way towards IPM and durably propel the Thai cotton industry into a recovery phase.

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