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REVIEW

Research with a farming systems perspective needed for the development of small-scale aquaculture in non-industrialized countries

Ludwig C.A. Naegel

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Ensenada, Baja California, México

The global rise in the production of farmed fish and shellfish in non-industrialized countries has been supported by aquaculture research aiming most often to solve problems for factory-like production of highly valued aquatic species. It can be observed however, that research at the small-scale aquafarmers' level is lagging behind. Research with the holistic farming systems perspective and farmers' participation offers a chance to support aquaculture production at the small-scale farmers' level in non-industrialized countries.

KEYWORDS: Aquaculture development, Developing countries, Farming systems research

INTRODUCTION

The worldwide annual aquaculture production of fish and shellfish increased from 6.4 to 13.9 million tonnes (mt), between 1984 and 1992. During this period fish production increased from 4.4 to 9.7 mt, with 87% coming from non-industrialized countries, mainly from Asia (FAO, 1994). Aquaculture research, multilateral and bilateral aid, and technology transfer have supported this development. Additionally, profitable results attracted the interest of the investment community. Main goals in aquaculture research were to solve problems for factory-like production of highly valued aquatic species (Ben-Yami, 1986). The principal beneficiaries of this development have all too often been wealthy and powerful investors. Typically, in industrial aquaculture, as in all other commercial undertakings, economic profit is the decisive factor for operation. Adverse environmental effects are generally recognized only when the environment is already degraded, and socio-economic and cultural issues are rarely considered (Folke and Kautsky, 1989). This is an especially serious problem in some non-industrialized countries, such as Ecuador, Thailand, China and the Philippines, where significant aquaculture expansion has occurred without the capability to control effectively the industry's expansion and monitor potentially adverse environmental and social impacts. From an anthropological perspective, commercial aquaculture can negatively affect the rural poor, by competing for resources, altering familiar working patterns, increasing unemployment and degrading nutrition (Weeks, 1990). Additionally it has to be mentioned that the population growth in non-industrialized countries has significant

Correspondence should be addressed to: Ludwig C.A. Naegel, CICESE-Acuic, P.O. Box 434844, San Diego, CA. 92143–4844, USA.

impact on the arable land area available per farmer. In 1975 the average land holding per farmer was 0.81 ha. By 1989 it had shrunk to only 0.69 ha/farmer. In industrialized countries in contrast, the land area per farmer increased during this period from 8 to 12.5 ha (FAO, 1990a). During the 1960s and 1970s aquaculture was promoted at the marginal farmer's level to provide animal protein for the poor. This enthusiasm has since faded, since the results have been often far below expectations (Martínez-Espinosa, 1992). Much of the early excitement about aquaculture was based on the idea that low-cost cultured fish and shellfish could be produced with minimal technical inputs, make a significant contribution to rural development and help in alleviating malnutrition. It is now clear, however, that commercial aquaculture operations are more responsive to the domestic and export market demands, since supplying affluent consumers is more profitable (Kent, 1986). Additionally, investors normally seek high profit production, e.g., high-value species in the case of aquaculture. Governmments can, however, determine the fate of aquaculture through support measures and taxation. Modern aquaculture farming practices and research often put the emphasis on profitable, rather than resource saving production, specialization rather than whole farming systems development, short-term efficiency rather than long-term sustainability, problem-solving directed at crises rather than at the future health and maintenance of the aquacultural system, and policy response to special interests rather than to a balance of public interests. The direction of aquacultural research should be changed to include the needs of resource-poor farmers, through research using the holistic farming systems perspective.

Conventional aquaculture research and teaching

Although aquaculture is closely related to agriculture and has been practiced for thousands of years, it is a relatively new discipline as an academic field. In promoting aquaculture development, much can be learned from experiences in agriculture. Unfortunately, until now the majority of agricultural universities have devoted little attention to aquaculture which is generally considered as a sideline of capture fisheries, with which it has only biological research, processing and marketing in common. With luck agricultural students may have a course on 'Production of unconventional animals, including fish', or for students taking aquaculture, a course on 'Integration of aquaculture into agricultural production systems'. In addition, the research output and teaching programmes of most institutions involved in aquaculture remain narrowly focused on basic biological questions, rather than on applied topics, not to mention the farmer and his/her household farming system. This is not surprising, as most of the scientists involved in aquaculture were educated in natural (principally zoology) or in aquatic sciences (particulary fisheries and oceanography), and stay within their primary disciplines (Smith, 1988). According to a recent survey, nearly 50% of the publications of the more than 400 members of the Asian Fisheries Society were on general biology and only 16% and 14% on aquaculture and fisheries, respectively (Eng and Maclean, 1988). A similar situation exists in Mexico – of 620 research projects, nearly 60% are in general biology, 9% deal with nutrition and feeding, 9% with technological problems, 7% with pathology and diseases, and only 3% deal with pollution and the impacts of aquaculture on the environment (FAO, 1989). A similar trend emerges by evaluating the research papers presented at the First and Second Asian Fisheries Fora and at the 1993 World Aquaculture Conference: about 80% of the papers were on topics of basic and strategic importance, and less than 20% on applied and adaptive research. This indicates that the majority of aquaculture scientists are engaged in basic and background studies and have more orthodox interests than the applied aspects of aquaculture and fisheries.

Progress in the factory-like production of aquatic organisms is driven by economic interests. For this reason, tremendous efforts are directed to the production of high value fish species, such as sea bream (*Sparus* spp.), salmon (*Oncorhynchus* spp.) and trout (*Salmo* spp.) or to the farming of abalone (*Haliotis* spp.) and shrimp (*Penaeus* spp.). Progress in these areas was boosted through research supported by industry. There are many reasons why scientists so effectively serve the commercial aquaculture operations. Environmentally, the physical and access conditions under which the aquaculture industry works are similar to those of research institutes. Methods developed at institutes will usually work well in the industry. In general, aquaculture industries are concentrated in 'core' areas of high potential, such as the alluvial plains and deltas, where both physical conditions, such as soil and water, and social and cultural conditions are relatively uniform, so that successful innovations tend to be widely applicable and easily disseminated. Additionally, areas with a functioning infrastructure, such as roads, electricity and communication systems are selected for investment in aquaculture. Politically, resource-rich producers in non-industrialized countries are articulate and influential, and often have funds to influence or sponsor research. Socially, most aquacultural scientists share class, professional attitudes and values with the wealthy producers with whom they interact. Methodologically, normal aquacultural science is reductionist, excelling in exploring the relationships of a restricted number of variables under controlled conditions. This suits the large-scale simplified aquaculture industry, in which the natural environment is highly controlled, with only one species under culture and the production, management and feeding regimes standardized (Chambers and Jiggins, 1987). It is important to stress that research is not necessarily of benefit to all farmers. Early adopters of a new technology certainly benefit up to a point, at which a certain proportion of farmers have adopted this new method, causing declining product prices and creating a technological treadmill. In the agricultural population the resource-rich farmers and early adopters are a minority, while those who receive little or no benefits from research are generally a majority (Buttel and Busch, 1988). Speaking about high-value shrimp farming in Colombia, Weidner *et al.* (1992) state that formal research in aquaculture is limited and inadequate and is not addressing the many basic questions and practical subjects that growers would find most useful. For these reasons it is not surprising that some Colombian growers believe that much of the research in aquaculture is of limited use to them. According to Tacon (1994), the majority of studies on the dietary requirements of farmed fish, especially omnivorous warm water species, have little or no practical applicability. This is because the bulk of these studies have been conducted in the laboratory and not under conditions resembling (as closely as possible) those of the intended farm production unit and environment. This is due to the reluctance of the conventional laboratory-based fish nutritionist to work under applied field conditions and the difficulty of quantifying the contribution of natural food organisms in the overall nutritional budget of pond-raised fish. Where is the research that could help the resource-poor fish farmer in non-industrialized countries to increase the production of low-cost species without destroying the environment and overexploiting natural resources? Generally, conventional agricultural/aquacultural research has a bad reputation with resource-poor farmers, since the conditions of aquaculture at this level differ dramatically from those of the industry and research institutes. Environmentally, small-scale aquaculturists have less control over physical conditions (flat land for ponds and water), less access to inputs (stocking material, pumps, fertilizer, feeds), different priorities (firstly, food and family, secondly, harvest for sale, and risk reduction), often a farming system with complex interactions (integrated aquaculture/agriculture production, polyculture of aquatic organisms), and multiple household enterprises (off-farm income). In contrast to the relatively uniform conditions of the 'core' areas, the areas in which most resource-poor farmers live are ecologically and culturally very diverse, demanding highly differentiated and local-specific research. Politically, resource-poor aquaculturists are not well organized and lack resources to sponsor official and commercial research or effective lobbies to influence it. Socially, scientists with a different class, professional and sometimes cultural background often find it diffficult to interact with these farmers (Chambers and Ghildyal, 1985; Chambers and Jiggins, 1987).

Lightfoot (1990) warns that the present ways in which farmers use land and water will not meet the projected demand for food and money for the 21st century, and that commodity yield increases through research on individual crops, including fish, will not suffice. There is considerable evidence that greater emphasis on general education of farm and rural people contributes significantly to the development process. Wherever agriculture is included in the primary school curriculum, basic scientific procedures and reasoning, an introduction to agricultural methods, and the relationship between environment-based agriculture and science should be taught. The main objective of teaching should be to enhance practical skills and knowledge and to develop positive attitudes towards manual labour. Students should feel that field work is not a punishment but a valuable experience for understanding the theories taught in class (Bergmann, 1985). Agricultuural education institutions, including universities, justify their existence as preservers of knowledge, as if it were a commodity which can be stored by a custodian – the teacher, to be given to a recipient – the student. The functional breakdown between teaching and research further reinforces this situation (Ison, 1990).

The separation of agricultural education, research, extension and administration from corresponding activities in other disciplines is one reason for 'tunnel vision' of researchers locked within narrow disciplines and sectoral issues. This is because they think of short-term solutions to problems and not about flexible options from which to choose the appropriate alternative for the continuously changing needs (Lightfoot, 1990).

College students preparing for careers in agriculture can, if they wish, take curricula in which agricultural subjects are so predominant, that the student can hardly be called educated in any broad sense. On the other hand, everyone else is likely to have limited exposure to even the rudiments of how our agricultural system works, a remarkable omission in general education in light of the importance of agriculture in everyday life. The same separation exists in research. There is economics, and there is agricultural economics; chemistry, soil and water chemistry; zoology and animal sciences; engineering, and agricultural engineering (Lockeretz, 1984). Liebhardt (1992) describes the situation: 'Contemporary Western science looks at an increasingly complex natural world by breaking it down into specialized disciplines. We have become so good at doing this, we have created more and more subfields with each specialist concentrating on the detail and distinctions within the field while disregarding the wider structure that gives any problem content. Today we at the university share a departmental label with colleagues with whom we cannot dicuss our daily activities. This patchwork approach leads us, like the blind man encountering the elephant, to offer entirely different perspectives on the same reality. While we drill holes in the wall of ignorance, we often ignore great chunks entirely. In fact, the more we specialize, the less chance we have of offering our knowledge integrated into a useful, meaningful whole. Then, to further complicate things, each speciality has created its own language, its own unique terms to communicate with other specialists in the field. A college of agriculture today is a world of many small countries, each with a unique language, each looking at the same process in isolation and then sending representatives to a U.N. without interpreters'. Forti *et al.* (1982) describe the present situation of scientific research and social goals: 'Science has given us an understanding of the world, classified by discipline, but little real comprehension of how these disciplinary perspectives can be assembled to provide a complete picture. The same is true for social problems. The effective response of science to these challenges depends first on how far scientists perceive their social responsibilities, and secondly how far they are prepared to transform that perception into relevant activity. They will need both scientific knowledge and understanding and a deep appreciation of society's goals. In the immediate future the greatest problem is not the accumulation of more specialized knowledge, but the concentration of integrative and 'holistic' knowledge which transcends disciplinary boundaries'.

For some scientists it may not seem appropriate to spend time with farmers, let alone with resource-poor ones. Laboratory work leads more readily and predictably to publishable papers which advance a scientist's career and result in a conventional professional recognition. There are strong reasons why agricultural/aquacultural scientists should follow the established way of research. At the national and international level, there is the prestige attributed to 'high technology' seed breeding and the use of expensive and sophisticated equipment and methods of research. Then there is the personal convenience in working in an office or laboratory, and on a research experiment station rather than on a farm or with farmers. Further, for gaining professional recognition, in-laboratory and field-station work in controlled environments is preferred. On the other hand, the environments of resource-poor farmers are very complex. There are many stresses and interactions and, moreover, the research methodology for such environments is not well established. It is safer for professional advancement and recognition not to share the farmer's risk. Professional values take modern scientific knowledge as superior, advanced and sophisticated, and little appreciate or respect the knowledge of farm families. At a deeper psychological level, the values and thinking which place the scientist on a pedestal, generating new knowledge and dispensing it to the surrounding masses, are personally gratifying (Chambers and Ghildyal, 1985).

Increased efforts in interdisciplinary research and development are needed in order to understand better the complete systems, the cycles and correlations of our earth, as well as the impacts of human activities on the environment. This understanding could lead to an economically and ecologically sustainable aquaculture, with low requirements for water, energy and fishmeal-based compounded feeds. Better knowledge could aid in the transformation of a high turnover aquaculture to methods where water, fuel and raw materials are used efficiently, where few or no wastes are produced, where residues are recycled, and where only compatible products are released into the environment. Research and development have to supply us with new technologies and with precise predictions about their wanted and unwanted impacts. To promote sustainable agricultural/

aquacultural development to feed the growing world population, international and national research systems are challenged to interdisciplinary efforts, to develop environmentally sound and sustainable technologies which can replace or improve the current ones without adverse environmental effects.

Flow of information and technology transfer

The last 20 years have brought increasing numbers of publications about aquaculture and agriculture, but the non-industrialized countries are lagging behind the mainstream of information. Among the problems facing researchers in non-industrialized countries is the acquisition of reference materials. Papers and books that appear essential for the success of a particular project may be practically unobtainable. Often the cost for books and journals is far beyond non-industrialized means. Additionally, the majority of scientific research occurs in industrialized countries, mostly in the northern hemisphere, and results often take considerable time to trickle down to researchers in remote areas in developing countries. Geographic isolation is not the only problem: in non-industrialized countries research budgets are slim and do not encourage subscription to journals and abstracting services. This lack of access to the latest information is a serious constraint on research, since scientists are being denied an essential tool of the trade (Dalzell, 1987). On the other hand, it is interesting to note that the tendency toward a nearly exponential increase in scientific publications is not restricted to industrialized countries. Only 11% of approximately 3100 literature citations on Latin American aquaculture were published before 1970, followed by 11% during 1970–1975, and 22% during 1976–1980. More than half (54%) appeared after 1980 (Saint-Paul, 1992).

Are the modern systems of information in the non-industrialized world an integral part of the 'transnational style of development' and are those systems biased towards the ends of the 'transnational community'? Latin American countries are trapped by an inability to advance significantly toward organizing, storing and disseminating the mass of information that arrives from outside (Crowther, 1984, cited by Harris, 1990). The inability to sort these data by previously defined national priorities affects all potential users of scientific, technical, and socioeconomic data, who must simply accept the priorities imposed by the information system. Meanwhile other, perhaps more valuable, data are not accommodated by the information systems of the transnational community. These data, which might reside mainly in the oral tradition of the farmer, or in unpublished reports or in the minds of colleagues, are ignored in the development process (Harris, 1990). A much stronger opinion about information and technology transfer is that by Wambi (1988): 'technology is like genetic material: it is encoded with the characteristics of the society which developed it, and it tries to reproduce that society, if the economic, social, and political environment is compatible with it and malleable. In short, elitist, capitalist societies that export high technology will reproduce elitist, capitalist structures in the importing countries'. In view of this controversial situation of research and information transfer, is it then not comprehensible that scientists in non-industrialized countries have the feeling of isolation – intellectual, political, organizational and cultural? A retreat into their air-conditioned ivory tower, implementing 'western style' basic research, often supported by funds from industrialized countries, is the psychological counter reaction. Gladwin (1989) states that researchers, like farmers, do not change because of external pressures and have developed strategies to allow them to survive in an often-hostile environment. Basic 'tunnel vision' research, publications which only a small circle of specialists can understand, and participation at international meetings are such strategies for academic survival. The customary academic reward system, where the number of publications, theses directed, and participation at meetings serve as the main measuring stick for the evaluation of the productivity of scientists, supports this direction. Scientists are under strong pressures to get publications and technologies out, but helping people to manage those technologies is not considered part of the job. Few development specialists stay around after the honeymoon is over, when project enthusiasm comes face-to-face with daily operation (Rhoades, 1989). Until recently it was assumed in agricultural development circles that if a technology works in a technical sense, if inputs are available, and the technology can be calculated as profitable, then it should stand a good chance of success. Lately a 'social' and 'cultural' dimension has been added to monitor adoption or define the sociocultural constraints to adoption. Further, and usually overlooked, the target beneficiaries must be able to manage the new technology for a successful implementation of an agricultural activity. In non-industrialized countries, as Rahman *et al.* (1989) describe, socio-economic factors are most important. The questions are about land-tenure patterns, size of holdings, access to markets, legal protections, and the availability of services, such as credit and farm inputs. How farmers respond to these factors, or more specifically, what farmers do under a given set of conditions, determines the nature of a farming system. To understand this farming system, one must thus consider the farmer's goal, his resource base and the socio-economic environment. The generation of technology, extension, and acceptability are certainly important, but alone they will be meaningless without attention to the continued, long-term management of agricultural technology by farmers and national agricultural systems (Rhoades, 1989). However, this 'natural' development of agriculture and aquaculture with the farmer himself as the 'developer' is too often judged as too slow for solving the most pressing agri-aquacultural problems in most non-industrialized countries. The need to develop a new research strategy to more efficiently reach small-scale farmers is evident.

Research with a farming systems perspective to promote small-scale aquaculture development

The small-scale aquaculturist in non-industrialized countries is confronted with a whole catalogue of constraints, beginning with questions of land ownership, lacking infrastructure, training, and credit facilities, difficulties in obtaining seeds and feeds, up to the danger that the crop might be stolen (Shang, 1990). Resource-poor farmers in non-industrialized countries are often little educated or even illiterate, yet, they are knowledgeable (Brady, 1981). Chambers (1980) describes them as professionals in their field. Multi- and interdisciplinary to satisfy their farm and household objectives, they are, among other things, management specialists in acting as entrepreneurs, labourers and supervisors. They are soil scientists in managing land and matching crops to soil conditions, and economists in allocating scarce resources among competing, diverse enterprises (FAO, 1990b). Farmers, as well as scientists, know a great deal but, of course, they do not know everything. There can be no doubt that information from farmers can be exceedingly useful for research, e.g. in analyzing past trends in resource quality and some underlying reasons for these trends. However, many processes that threaten the quality of agricultural resources cannot be observed with the naked eye, and farmers know little of the future and its technology (Lightfoot *et al.*, 1993). A cooperation of farmers and researchers working in aquaculture research with a farming systems perspective, as well as with disciplinary and commodity scientists, is therefore of mutual benefit. Greater participation from the farmers' side will come through building farmers' skills in experimentation. On the other hand the researchers need more than scientific competence. They need to learn new ways of thinking. Establishing permanent relationships with small-scale farmers one can try to exchange farmers' knowledge for the knowledge of the researcher. This type of exchange does not mean extending something from the 'seat of knowledge' toward the 'seat of ignorance' (Freire, 1977). Rather, researchers and farmers can become more active partners in the sharing of ideas and the generation of sustainable farming systems.

While most agriculture and animal husbandry is based on a small number of domesticated plant and animal species, in fish culture a larger number of species can be utilized. Additionally, aquaculturists are an heterogeneous group. In non-industrialized countries, they range from the small-scale, isolated farmers with a few tilapia in a kitchen pond to the multi-national corporation that runs a modern, sophisticated cage culture venture, and in between are large-scale farmers and urban middle-class members of society, like shop-keepers, civil servants, and teachers (UNDP/NMDC/FAO, 1987). This situation makes centralized research extremely difficult. Comprehensive farming systems research concerned with species and cultural procedures suited for different agro-climatic, economic, social and cultural conditions, is nearly impossible (Pillay, 1986). Results from aquaculture research are therefore generated in a large number of institutions in many countries. To collect these results and evaluate them for their usefulness under certain conditions, and to transfer the new, adapted technology is the responsibility of the researcher working in farming systems. Development teams (including bio-technologists, social scientists, economists and extension workers) are engaged to discover, more rapidly than the farmer himself could do, how to improve existing practices, either by modifying them or by replacing/introducing exotic species and culture systems (UNDP/NMDC/FAO, 1987). Research with a farming systems perspective offers a possibility to close the gap between science and the small-scale farmer.

What are farming systems and what is farming systems research?

Small-scale farmers in non-industrialized countries are economically rational and generally willing to adopt innovations that they consider economically advantageous. Most live in highly unpredictable environments, where input and marketing infrastructures are often unreliable. Marginal farms are operated within the context of scarce resources and constant concern to meet the basic needs of the farmer's family. Since the income is inadequate, farmers cannot afford to take risks (Pineiro, 1989). They require high returns from any farm innovation to offset the risk associated with its adoption and the extra effort required in family labour. As Donaldson (1991) reports from World Bank experiences, smallholders often require an increase in yield that will pay a return of 200% to assure adoption of a new technology package. Recognizing this situation, the objectives of research must be defined by the specific needs of farmers within the circumstances in which they live and work. All too often, research objectives are based on the preconceptions of scientists who have little appreciation of the real problems of small-scale farmers (IDRC, 1988).

The Consultative Group in International Agricultural Research (CGIAR) defined farming systems as a complicated, interwoven mesh of soils, plants, animals, implements, workers, other inputs, and environmental influences, with the strands held and manipulated by a person called 'the farmer' who, given his or her preferences and aspirations, attempts to produce output from the inputs or technology available. It is the farmer's unique understanding of the immediate environment, both natural and socioeconomic, that results in a farming system (Plucknett, 1988), and farming systems research (FSR) is a methodology for identifying the major needs for improved productivity and for testing and modifying new technological ideas on fields and under farm management (ADB, 1989). Farming systems research, which attempts to understand as fully as possible the living and working environment of a farming family, is proving to be effective. It is an holistic approach involving, not only individual commodities or enterprises, but also their interactions. It accounts for the opportunities and constraints of the social and economic, as well as the physical environment of the target farming communities. FSR involves the farmer in all stages from diagnosing researchable problems, through designing and testing solutions, to validating and disseminating appropriate technologies. This invariably demands a multidisciplinary team approach, with much of the research carried out on the farm, often under the direct management of the farmers themselves. Special attention is given to support improved stability and sustainability of production, and solutions are sought that are safe both to the environment and to human health (IDRC, 1988). The primary objective of FSR is the improvement of the well-being of individual farming families by increasing the productivity of their farming system, given the constraints imposed by resources and the environment. It consists of following two main thrusts towards increased productivity:

(a) development and dissemination of relevant improved technologies and practices, and
(b) implementation of appropriate policy and support systems to create opportunities for improved production systems and to provide conditions conducive to the adoption to technologies already available (Norman and Collinson, 1987).

The Australian Centre for International Agricultural Research (ACIAR, 1987) described in more detail the characteristics of FSR: It relates to smallholder subsistence oriented agriculture; the research project is multidisciplinary and holistic in perspective; the farmer is involved in all phases of the research project; the research is applied rather than basic, tends to be medium-term rather than long-term, and is aimed at generating viable technologies; it involves the farming systems description, diagnosis and problem specification, on-station solution design, testing, and verification; and finally the extension of the research results, training and policy formulation for extension support.

Strategies for research and development under an aquafarming systems perspective

A sustainable approach to small-scale aquaculture development means using local inputs, selecting well-adapted aquatic organisms, developing successful methods with basic technologies, increasing species diversity, coordinating aquaculture and crop production with other rural enterprises, involving farmers in planning, experimentation and evaluation, and encouraging community participation and decision-making. Ensuring sustainable rural aquafarming development means taking into account the knowledge and experience of farmers as well as scientists specialized in commodity, disciplinary and farming systems research. Such a development programme must be coordinated with broader programmes in land and water management, socio-economic development and the conservation of biodiversity. This calls for a broad interdisciplinary approach. To combine the knowledge of western trained scientists and farmers, researchers working in rural aquaculture must reject an arrogant dismissal of 'non-scientific' knowledge without adopting the naive view that farmers always know best. Researchers working in rural aquaculture must also use innovative methodologies to actively involve farmers in observation, experimentation and adoption of general FSR and development principles to local conditions. When farmers meet scientists on equal terms, both gain. It is often difficult for an outsider to gain access to the knowledge and experience of farmers. the methods applied in FSR facilitate this first challenging step by focusing on the small farm as the basic system and by incorporating the farmers themselves at all stages. These include a wide range of approaches with strong conceptual and methodological similarities, such as the rapid rural appraisal (RRA) approach, developed among others by Hildebrand (1980–81; 1981), the agroecosystem analysis, shaped by Conway (1986), participatory rural appraisal, pictorial mapping, and many others. As a rule, in the RRA approach semi-structured group interviews and ranking exercises are used to bring farmers' knowledge and priorities into the rural aquaculture research and planning process. Research based exclusively on aquacultural problems as perceived by scientists may not address farmer's priorities and needs. A more interactive approach suits resource-poor, risk prone farming environments better than standard technology transfer methods, which frequently result in innovations that are rejected by the farmers. Farmers will not adopt a new aquaculture method if it increases the risk, adds to labour demands, competes with other farm enterprises, requires sophisticated technologies, or causes a host of other problems that researchers might not anticipate. Participatory methods encourage local innovation and adaptation, accommodate and enhance diversity, strengthen local capabilities and are more likely to generate sustainable practices. To promote rural aquaculture development, researchers need more than scientific competence. They need to learn new ways of thinking. Training programmes must change attitudes and values as well as develop technical expertise. One proposed educational model includes role playing, conflict resolution and field exercises. Teachers are facilitators, catalysts and consultants in a learner-centered classroom environment. Students co-teach courses, design their own curricula and evaluation systems, and explore analytical thinking along with 'open' divergent thinking.

Research, education and training in the Peoples Republic of China: a possible signpost for rural aquaculture development in non-industrialized countries

Traditional Asian aquaculture is self-reliant and low cost, representing a model for aquaculture elsewhere in non-industrialized countries. It has developed over centuries, with the farmer/aquaculturist playing the main role, under the guidance of local leaders. The farmer experimented with species and culture systems which he knew would be acceptable in the community and which would not use an unreasonable amount of resources (UNDP/NMDC/FAO, 1987). From the worldwide 9.7 mt of farmed fish, 5 mt come from China alone (FAO, 1994). Aquaculture development in China, however, must take place under the conditions of a large increasing population with declining arable land per person (1989: 0.088 ha/person), insufficient grain and food supply, and a low level of animal protein consumption (Leung *et al.*, 1993). At a consumption level of 10.1 kg of fish per year, fish is supplying more than 4% of the total and nearly 20% of animal protein consumed (FAO, 1993). In view of these facts it is interesting to examine the importance of research for the development of aquaculture in this country, and to explore if some characteristics could be adopted or adapted in other developing countries. The aquaculture policy adopted in China is that research, education and training should serve production. In putting this into practice, they have adopted what they call an 'open-door' policy of research and teaching. This policy is implemented through 'three-in-one' combinations. Leaders, researchers and worker/farmers identify production problems together and work together to solve them. Each group teaches and learns from each other. Furthermore, the unity of 'theory with practice' is more than just talk; in the FAO mission's view, it seems to be a firm rule at all levels of research, education and training. A practical effect of these working policies has been that even artificial fish propagation is now commonly and widely practiced by ordinary fish farmers in the countryside. In contrast, in most other countries this is highly specialized and usually done only by scientists and trained technicians (Tapiador *et al.*, 1977). The often cited benefits for small-scale farmers in integrating aquaculture into their agricultural production system are certainly real, provided that the marginal farmer has access to a piece of land and to fitting credits for the purchase of the necessary inputs, and can obtain a fair price for the product. The political structure enables farmers to plan their programmes to meet local needs. At the same time the collective ownership system of production has enough resources and skills to meet those needs. Since planning and implementation are done at the local level they achieve effective integration and parallel development of related sectors. As Tapiador *et al.* (1977) clearly stated, in China there is a full integration of fishery and fish culture with water conservation, agriculture, forestry, animal husbandry, sideline occupations and intensive use of land and water resources, especially at the farm level.

The economic reform in China and the introduction in 1980 of the contract responsibility system where remuneration of the individual aquafarmer or household is linked to the output generated, increased interest in fish farming and has led to a tremendous growth in productivity. The new system blends the advantages of unified collective management and the enthusiasm of individual or household production and management. It has stimulated competition and connected farmers' individual interests to earn a higher income with production, creating much enthusiasm and initiative. The results were increased production, reduced costs and economic efficiency. In pond fish farming during the period from 1979 to 1990 the average yield rose from 722 to 2,381 kg ha^{-1} combined with an increase of pond area of more than 11% y^{-1}. During this period, total annual production from pond fish farming rose nearly six times from 544 000 to more than 3 mt. To reduce production costs Chinese fish farmers have created many different integrated fish farming systems, including fish with poultry and domestic animals. With this production costs could be reduced by about 50% (Leung *et al.*, 1993). However, integrated farming systems are presently used only in a few countries by an insignificant minority of farmers, and have not progressed far in terms of productivity and efficiency from their traditional beginnings (Smith, 1988). In the Philippines, for example, the widespread application of rice-fish culture has been hampered by poaching, the farmers' lack of motivation and innovativeness, and such technological problems as the application of pesticides, the unavailability of fingerlings, and inadequate water supply (Bimbao *et al.*, 1990).

CONCLUSIONS

To promote aquaculture at the subsistence aquafarmers' level in non-industrialized countries, it is essential to understand the complexity of the total farming system. Narrow disciplinary and commodity research is to be avoided and the whole farm household, with its multifaceted problems, needs and objectives, must be included, considering the complexities of agro-ecological and socioeconomic processes. Research with a farming systems perspective offers just such a possibility. There is great potential for increasing productivity of limited land by integrating aquaculture into the existing farming system. However, before introducing a new technology, one must take into consideration the concerns, cultural, socioeconomical and political conditions of the subsistence farmer.

Rural agricultural/aquacultural development is concerned with promoting change toward higher levels of productivity, consumption, welfare and social organization without environmental degradation. Since development in aquaculture at the small farmers' level can only be brought about by widespread and gradual increases in productivity, research must concentrate on developing technologies and innovations appropriate to the conditions of the subsistence farmer, adaptable to limited land and water resources, and responding well to low input derived mainly from local sources. In view of the complexity and instability of the small-scale farming system, great care is required in selecting the appropriate technology. Additionally, to promote aquaculture development with limited resources and to increase the income of the marginal farmer's family, sufficient resources must be available for training in efficient water management, aquaculture, diversified cropping, for fingerlings and seeds, fertilizers and farm implements. The appropriate and adequate technology for the integration of aquaculture into existing agricultural farming systems, as well as additional resources are not the only objects needed to keep the operation and growth of the production system moving. There is also the need for markets and fair prices for the produce, availability of inputs, and an adequate credit system for their purchase. Even the availability of fingerlings for resource-poor farmers is an obstacle for the development of integrated agricultural/aquacultural production sytems.

Technology *per se* is not sufficient to bring about significant changes in the current economic and social situation of small farmers in Latin America (Pineiro, 1989). It can, however, be the central component of a start-up strategy designed to strengthen small farms, favouring their differentiation towards a situation in which they can adopt other technologies and in which they will have greater management capability – all of which would foster savings, self-sustained growth and improved living standards.

In the past aqua/agricultural technologies developed at national and international research centres often failed to produce a technology directly applicable to the situations of the marginal farmer, where capital is scarce and manual labour prevails. Non-industrialized countries did not profit as much as expected from the specialized academic training and 'tunnel vision' of many scientists. The needs of the millions of smallholders in the tropics, farming under disadvantaged conditions in diverse and risk-prone environments, have been neglected. To change this situation, technology development must be a process of purposeful and creative interaction between the subsistence farmer, the local community and the researcher. The traditional knowledge and experiences of the farmer with the accumulated scientific information and with modern tools may be blended into new or adapted technologies and systems, which comply with the needs and environments of the marginal farmer.

In addition, an economic, social and political environment has to be created that will encourage the adoption, adaptation and dissemination of new technologies and farming systems. Needed inputs and a fair marketing system must be available. Universities, national and international research centres, governmental and non-governmental organizations have key roles to play in helping to identify needed policy changes and to encourage their implementation. Linkages between scientists and institutions from industrialized and non-industrialized countries, such as ASEAN-EEC Aquaculture Development and Coordination Programmme (New and Kongkeo, 1995), have to be established to accelerate cooperation. Such cooperation will strengthen the concept that sustainability in aqua/agriculture is not only a regional but an international problem and opportunity.

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