APPROPRIATE USE OF LOCAL RESOURCES IN INTEGRATED FARMING AS A STRATEGY FOR SUSTAINABLE AGRICULTURE IN CENTRAL VIETNAM

by

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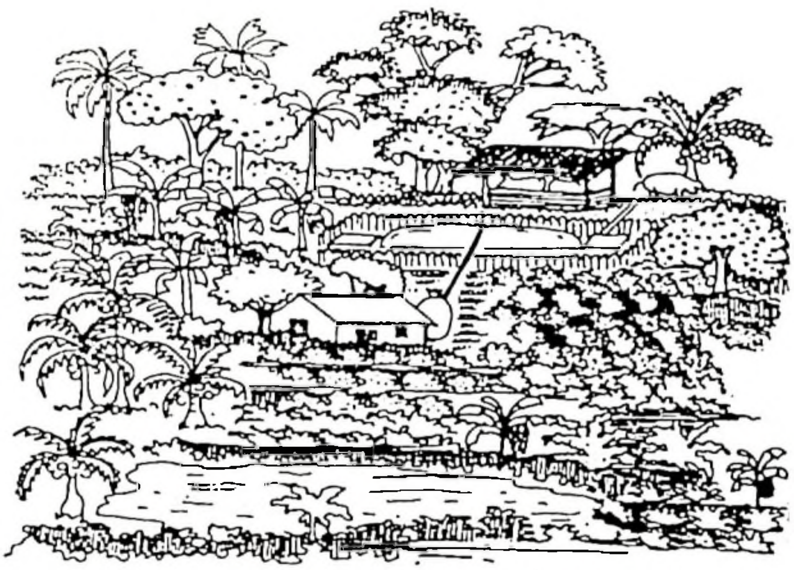

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To my parents German and Graciela...
To the small scale farmers in Colombia and Vietnam...
and to those people with "conviction" that have contributed to rural development in tropical countries...

PREFACE

This thesis is based on the following papers, which are refered to by their Roman numerals:

I. Rodríguez Lylian, Preston T R and Dolberg F 1996. Participatory rural development: "Experiences in Binh Dien and Xuan Loc villages in Central Vietnam" (manuscript)

II. Rodriguez Lylian and Preston T R 1996 .Use of effluent from low-cost plastic biodigesters as fertilizer for duck weed ponds (manuscript)

III. Rodriguez Lylian and Preston T R 1996. Comparative parameters of digestion and N metabolism in Mong Cai and Mong Cai*Large White cross piglets having free access to sugar cane juice and duck weed (*lemna minor*) (manuscript)

CONTENTS

APPROPRIATE USE OF LOCAL RESOURCES IN INTEGRATED FARMING AS A STRATEGY FOR SUSTAINABLE AGRICULTURE IN CENTRAL VIETNAM

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1. ABSTRACT

The research was conducted from February 1995 to February 1996 in the Socialist Republic of Vietnam . Located in the Asia-Pacific region, Vietnam has an area of 329,560 km^2 and its population is over 70 million people. The overall objective was to devise ways of making better use of the local resources, especially the livestock, in order to improve the well being of the people.

The first study was carried out in two villages in a rain-fed hilly region in Central Vietnam (Paper I). The original idea of evaluating an intervention based on restricted milking of the local cattle was abandoned in the light of the insistence of the farmers that the expected benefits were too long term and they had other more immediate priorities. In contrast, discussions about the potential benefits from introducing low-cost biodigester technology were enthusiastically received, especially by the women.

The traditional diet for pigs in the region is lacking in protein. Conventional protein supplements are expensive and their availability is low. Biodigesters produce nitrogen-rich effluent and are a logical source of the required nutrients for growing aquatic plants such as duck weed as a local source of protein. Thus there was a potential connection between the biodigesters (being installed primarily as a source of fuel) and the need to improve the diet of the pigs.

It became apparent during the development of the "duck weed" project that there were many factors which influenced duck weed production, some controllable and others determined by climatic conditions (flooding!). Management was found to be the most important factor --eg. the levels of effluent to be used, water exchange and the need to renovate the seed. Very little was known in the use of the biodigester effluent to produce duck weed in such conditions, so this aspect was a logical subject for "on-station" research (Paper II)

In Paper II the hypotheses to be evaluated were that: effluent from biodigesters would be an effective source of nutrients with which to grow duck weed of high protein content; and the protein level in the duck weed would be a function of the amount of effluent added to the pond water. Six ponds were used, each lined with polyethylene film (0.2mm thickness) having 9.4 m^2 area and 15 cm water depth. The two treatments were 32 and 4.5 kg effluent/m^3 pond water which were estimated to support N concentrations in pond water of 73 and 10.3mg N/litre respectively. The effluent was from plastic tube continuous flow biodigesters, charged with pig manure, and contained 6.5% of solids and 3.41% of N in the solids. 200 g of duck weed/m^2 were added to each pond and the total biomass was harvested at 3 day intervals over a period of 9 days. Biomass yield and protein (N*6.25) in the duck weed dry matter were linearly related with the N concentration in the pond water and negatively related with root length of the duck weed. Optimum levels of N in pond water were in the range 40-60mg N/litre. Duck weed of more than

35% protein had a root length less than 10mm. Duck weed biomass yield at optimum pond N levels was of the order of 100 g fresh biomass/m²/day with 6% dry matter and 30-40% protein (N*6.25) in the dry matter.

As a result of the project activities in the village and based on farmers expectations, research to document the local breeds became a priority. A survey was done to get some baseline data. These observations at village level about the efficiency of the Mong Cai breed in the use of local resources were the basis to carry out an "on-station experiment" to explore the digestion parameters and N metabolism of Mong Cai and exotic breeds and their crosses (Paper III).

The hypotheses to be evaluated in paper III were: (i) Mong Cai pigs would eat greater amounts of duck weed (*Lemna minor*) and use it more efficiently than exotic pigs such as those of the Large White breed; and (ii) duck weed grown in ponds fertilized with biodigester effluent would be a satisfactory source of supplementary protein in a low protein basal diet of sugar cane juice. Four Mong Cai male piglets (5-10 kg) were obtained from the local market; four Large White male piglets (12-17 kg) from a nearby State farm and four Mong Cai*Large White piglets (2 male and 2 female) (9-14 kg) from a litter (Mong Cai mother; LW sire) born at the farm. They were housed in metabolism cages made from bamboo and wood (floor area 70*70 cm) with freedom to move around

Relationships between the percentage of diet dry matter consumed as duck weed (X) and apparent digestibility (DM and N) and N metabolism (retention as % of intake and digested N) were derived for the combined data for the 2 breed groups (8 pigs) and expressed as linear equations, the regression coefficients of which were all significantly different from zero.

There were no significant differences between Mong Cai and Mong Cai*Large White crosses for any of the parameters and the results indicated that the nutritive value of duck weed is high when fed to indigenous pigs and their crosses as a supplement in a basal diet of sugar cane juice. Fifty percent of the pigs were able to consume fresh duck weed in proportions sufficient to provide a diet with more than 10% of protein in the dry matter. Purebred exotic pigs (Large White) appeared to be less adapted to consume the duck weed.

Key words: Sustainability; Vietnam; Women; On farm research; Extension; Milk production; Low cost plastic biodigester; Effluent; Duck weed; Lemna; Integration; Ponds; Nitrogen; Protein; Pigs; Indigenous breeds; Animal welfare; Mong Cai; Energy; Sugar cane juice; Digestibility; N balance; Biodiversity.

2. INTRODUCTION

In the countries of the Third World, some 2.3-2.6 billion people are supported by agricultural systems characterized by modern technologies brought about by the Green Revolution. These systems utilize good soils and usually have reliable access to water, and are close to the roads, markets and supplies of inputs. However, these systems are not applicable to the 1.9-2.2 billion people living in rain-fed, undulating and mountainous areas, which are largely untouched by modern technology. They tend to be in the poorer countries with little foreign exchange to buy external inputs. Their agricultural systems are complex and diverse, and are located in the humid and semi-humid lowlands, the hills and mountains, and the drylands of uncertain rainfall. They are remote from services and roads, and they commonly produce per unit area only one-fifth to one-tenth of the food as farms in the industrialized and Green Revolution lands (Pretty 1995).

The world population is growing very fast (Table 1). In 1950 it was 2.5 billion and increased to 5.3 billion by 1990. The projections for 2030 show the world population rising to 8.9 billion.

There is a growing disparity between the expanding world population and the earth's food producing capacity, the rate of increase of which is less than the rate of population growth. As a result, food supplies per capita are decreasing (Brown and Kane 1994). However, an important issue here is the role of livestock. As living standards rise, so does consumption of livestock products. But the feeding systems to produce these products, especially in the industrial countries, use the same feed resources as are eaten by humans , namely cereal grains and soya bean meal. It is estimated that almost 50 % of the world grain supply is consumed by livestock (Sansoucy 1995). It has been argued (Preston 1995) that if all the world's grain production was reserved for human consumption then there would be enough to feed the 10 billion inhabitants at which point the world population is expected to stabilize.

It is therefore a fundamental issue that any intervention involving livestock must be predicated on their synergistic role in benefiting the whole farming system rather than as producers of meat, milk or eggs using feeds which are in competition with human needs.

The tropics present great opportunities for sustainable development thanks to the enormous cultural and biological riches of these regions, the rational exploitation of which could support sustainable production in the medium and long term, but which have not been considered seriously in previous attempts to develop the livestock sector in these regions (Preston and Murgueitio 1994).

The sustainable use of natural renewable resources will be facilitated when the feed is grown, the animals are fed and the excreta is recycled on the farm in ways that minimize the use of imported inputs, including energy. Integrated farming systems that embody these concepts are seen in many parts of SE Asia and have developed in response to increasing human pressure on land resources (Preston and Murgueitio 1992).

If, as expected, fossil fuel prices increase in the long term at rates exceeding average inflation in the industrialized countries, then one increasing role will be the use of livestock as sources of power in agriculture. The other issue, which perhaps relates more specifically to Latin America, and parts of Africa, is that the principal livestock production system is extensive grazing by large ruminants, the establishment of which has mostly been through the destruction of the natural ecosystems of the tropical rain and cloud forests. These systems have consolidated the position of the medium to large landowner/cattle rancher and, by so doing, minimized opportunities for the small scale farmer (Preston and Murgueitio 1992).

3. OBJECTIVES

The overall objective was to devise ways of making better use of the local resources. As it has been argued (Pretty 1995b) that the dominant positivist research paradigm has strong limitations, it was an important objective in terms of research strategy to test the farmer first and last model- FFL (Chambers and Ghildyal 1985) and the participatory learning model (Pretty 1995) as applied to livestock research. The researchers' immediate objectives were:

- To understand the system of production in the selected villages and the role of the cattle in this system.
- To study the possibility to establish a milk production programme to develop the "multi-purpose" (Preston and Leng 1987) use of the local cattle.

4. GENERAL DISCUSSION

4.1 How to develop sustainable farming systems?

There are so many aspects to consider in order to answer this question. Many farmers, scientists, researchers and students are concerned about the problem and are trying to bring about ways for sustainable development. It is not an easy task but not impossible if people combine experiences and efforts.

It is evident that development must be done based on the traditional systems of production. Everywhere in the world there are farmers who have for a long time maintained sustainable systems of production with good results. It is important to have open minds and be ready to study the experiences and techniques of these farmers, which perhaps could be improved, but often are ready to be transferred to other producers.

Education is fundamental issue in development. The world needs sustainable education. Are the new professionals ready to work with this approach? It is difficult when traditional teaching is focussed on technological packages as a consequence of the green revolution and when the major objective is to train people to work for the multi-national enterprises, to sell concentrates, veterinary medicines or pesticides. The professionals involved in the education system need to create a deep and wide conscience about appreciating the real situation facing poor farmers and what needs to be done in order to promote truly sustainable agricultural systems and to try to understand these issues (Rodriguez L and Preston TR 1995).

Livestock are enormously important to the economies of the less-developed countries as a whole. According to Brumby (1987) when, to the direct economic value of animal products, the value of livestock in providing rural transportation, draught power for cultivation, manure for crop production and their ability to utilize non-arable land and the agricultural residues is added, livestock accounts for about half the total agricultural production. Livestock also play a critical role in maintaining a cash flow for poor farmers who grow their crops essentially to provide food for their own household. Milk, meat and hides will always be sought after by those segments of society that have the necessary purchasing power to acquire these products. To the farmer-producer these products represent opportunities for generating income. In these systems, the close integration of livestock with crops is a fundamental concept.

4.2 What is the role of research in the development process?

4.2.1 On-station or on-farm?

In the past, especially in developing countries, research has been done mostly in experimental stations or universities but the results have rarely been of benefit to the small scale farmer and often were detrimental in terms of impact on the environment. A more appropriate approach is to focus the research on the reality facing the small scale farmer and complement this with supporting problem-based experimentation in the experimental station and university.

Another problem is that excessive centralization and inflexible management tend to suffocate new initiatives. The reward systems for researchers are usually based on scientific publications which often discourages them from working in the field, where research is less controllable and the topics may be seen as less scientific. The analysis by Gupta and colleagues (1989) shows how this translates into a repeated focus on "modern" methods of farming and widespread ignorance of alternative resource-conserving technologies and practices. They studied the abstracts of research and extension theses completed in 32 agricultural colleges and Universities between 1974 and 1984 (Table 2).

On-farm research has many advantages. Farmers have always experimented to produce locally-adapted technologies, practices, crops and livestock (Chambers et al 1989; Brouwers 1993; Scoones and Thompson 1994). They are continuous adaptors of technology and their systems are rarely static from year to year. Richards (1989, 1992) has linked this process of adaptation to a performance, in which the actors change the nature of the performance according to the specific conditions. The problem is that researchers commonly do not understand or even accept that farmers can be "researchers". They assume that farmers are conservative and bound by tradition. Static and unchanging practices can therefore, upon investigation at a particular time, be characterized, analysed and so developed. But such an analysis can give nothing better than a snapshot of a complex and changing reality. It is important therefore, to begin to see technologies in a different light, not as fixed prescriptions but as indicators of what can be achieved. What agriculture needs is a willingness among professionals to learn from farmers.

The "farmers first and the last model" (FFL), an alternative to the transfer-of- technology model (TOT), is based in the farmers perceptions and priorities rather than on the scientist's professional preferences, criteria and priorities. The starting point is the scientific learning from and understanding of the resources, needs and problems of the resource-poor farmers, and the research stations and laboratories play a referral and consultancy role. This model is characterized by the use of informal survey methods, research and development within the farms and with the farmers and evaluation through the technology adoption. (Chambers and Ghildyal 1985).

Compared to a conventional experiment station approach to research, farming systems research (FSR) approach is more comprehensive. It make demands on skills beyond the capacity of the individual scientist and a team of scientists has to be formed, representing different disciplines (Dolberg 1990).

4.3 Action programme

This study was carried out in two villages in a rain-fed hilly region in Central Vietnam within a broad conceptual framework of sustainable development. The original idea of evaluating an intervention based on restricted milking of the local cattle was abandoned in the light of the insistence of the farmers that the expected benefits were too long term and they had other more immediate priorities.

In contrast, discussions about the potential benefits from introducing low-cost biodigester technology were enthusiastically received, especially by the women. Over fifty biodigesters were installed in Xuan Loc and Binh Dien villages, and around Hue city. Officials both of the People's Committee and the Women's Union took an active part in the programme and became "trainers" of other farmers, as well as "maintenance technicians", offering help to neighbours who had problems with their biodigesters. An evaluation of the impact of the intervention was made by the women farmers who had participated together with officials of local aid Agencies. The result was a frank discussion of the problems and of the mistakes but with a final endorsement of the advantages of the technology. During the project activities there was concern on both sides (outsiders and villagers) about the follow up of the technology after the project ended. Therefore, the Women's Union developed a project proposal with the objective to secure development funds to ensure an extension of project activities, so that monitoring would continue of the biodigesters already installed and to facilitate the introduction of the technology in neighbouring villages. Visits by staff members of the Canadian embassy were made to the village and the proposal was approved by the embassy, on behalf of CIDA , at the beginning of December 1995.

4.4 Local knowledge - local breeds

As indicated earlier, the project activities in the villages of Binh Dien and Xuan Loc were changed to concentrate on making more effective use of the livestock excreta by recycling this resource through biodigesters. Following this first intervention, the farmers suggested that instead of developing systems of milking the cattle, they could generate more income by establishing pig breeding in view of the difficulty of obtaining weaners for fattening. They were especially interested in having the local pig breeds for the reproduction phase because they were prolific, had good mothering ability and were well adapted to local conditions.

A survey of farmers who had kept pigs of the indigenous Mong Cai breed showed that they had an average litter size of 11 at birth , of which 10 were raised to weaning. Many of the sows had continued reproducing and lactating for 8 cycles, farrowing at average intervals of 181 days. These data confirmed the confidence of the farmers in the local breeds.

4.5 Protein supplements are a major constraint

A second limitation to expansion of pig production was the difficulty of obtaining protein supplements because of the high cost of existing local sources (chiefly groundnuts) and the distance from the markets where protein-rich meals could be bought. At this time, on-station research at the University of Agriculture and Forestry of Ho Chi Minh city (which in turn had been stimulated by visits to local villages that were growing duck weed for sale and for feeding to ducks) was showing how the protein content of the duck weed could be raised by fertilizing the ponds with biodigester effluent. The high-protein duck weed was observed to be well accepted by pigs.

There was no experience in the Binh Dien and Xuan Loc villages of growing water plants although many farmers had ponds. The question of accustoming their pigs to eat duck weed was not felt to be a problem as one of the reasons for the farmers' preference for local breeds was because they were used to consuming a wide variety of green plants. Ten farmers in each village participated in the growing and utilization of duck weed as a supplement to the traditional diet. A further ten families in Binh Dien (who had offered originally to participate in the milk production scheme) began to raise Mong Cai gilts. The project work in the villages ended before quantifiable results could be obtained. Unprecedented flooding also caused a serious setback in the duck weed programme. However, most of the families persevered with apparently encouraging results. A typical response from several women (who look after the pigs) was that "growing duck weed was easier than growing sweet potato (the traditional vegetable fed to pigs) and the pigs preferred it and were growing faster".

4.6 On-station research with duck weed

Experience in the villages with introduction of the duck weed highlighted the need for more information concerning appropriate management of the ponds, especially the optimum levels of fertilization with biodigester effluent to maximise use of the effluent and the protein content of the duck weed. The acceptance and efficiency of utilization of duck weed by indigenous pig breeds was another issue that required further research.

Reports in the literature indicated that for duck weed grown on sewage water the optimum nitrogen level in the pond water was of the order of 40-50 mg/litre, in order to achieve protein levels in the duck weed above 35% in dry matter (Leng et al 1995). The experiments described in Paper II confirmed that similar relationships existed when biodigester effluent was the source of nutrients. It was also shown that root length of the duck weed was highly correlated with the protein content (r = -0.93) and the biomass yield (r = -0.70), and thus could be used as a rapid on-farm assessment of the quality of the duck weed and the adequacy of the fertilization of the pond water (r = 0.73 between root length and N content of pond water).

4.7 On-station research with local breeds and local feeds

There are few reports concerning the possible interaction in pigs between breed and feed supply. An experiment in Nigeria with indigenous and exotic genotypes fed high and low fibre diets showed no differences in digestive function between breeds but a need for adaptation to the diet, especially when this was of high fibre content. (Anugwa et al 1989).

The results of the digestibility and N metabolism trial with Mong Cai pigs and their crosses fed a diet of sugar cane juice and duck weed (Paper III) confirmed the absence of breed differences in dry matter digestibility and N digestibility and N retention. The failure to adapt exotic purebred pigs (Large White) to consume duck weed was attributed to the fact that these animals were born and raised with access only to cereal-based concentrates whereas the Mong Cai and their crosses had access to green plants (and to duck weed in the case of the crosses) from a few days after birth.

The evaluation of unconventional protein supplements, especially water plants and tree leaves, was facilitated by using sugar cane juice as the basal diet since this feed contains neither protein nor fibre.

5. CONCLUSIONS

On-farm research is a dynamic process. Farmers have always experimented to produce locally-adapted technologies. Farmers are often excellent "researchers" and "extensionists". In this way, research and extension go together, which is the ideal. When the research is done on-farm the process can be faster and there is a "natural selection" of technologies and priorities and therefore there is less waste of time and money. Applied in this way the "Farmers first and last model (FFL)" is an alternative to the transfer-of- technology model (TOT), and is based on farmers' perceptions and priorities rather than on the scientist's professional preferences, criteria and priorities.

Close collaboration and confidence between researchers, advisors and local leaders, institutions and organizations are important preconditions for successful "on-farm research and technology adaptation".

In some respects, especially when new technologies are being developed or adapted, it is advantageous if on-farm research is complemented with "on station" research, but there must be a clear understanding of, and link with, the reality of the farmer situation.

Milk production as another "purpose" for the local cattle which may have a potential. However, it may not be a first priority. Very few very poor people keep cattle, but they live off the environment by collecting and selling firewood. More work with pigs and poultry and appropriate credit arrangements are more likely to benefit them and thereby the environment.

Biodigesters can play a pivotal role in integrated farming systems by facilitating control of pollution and at the same time adding value to livestock excreta through production of biogas and improved nutrient status of the effluent as fertilizer for ponds and crop land.

Biodigester impact is variable, and adoption and successful results depend on aspects such as location (availability of fuel), the way in which the technology is introduced, supported, adapted and improved according to the local conditions and the technicians' attitudes.

Traditional diets for pigs lack protein and conventional protein supplements are expensive or are not available. Therefore when the biodigester is part of the system producing gas and effluent rich in nitrogen duck weed can be grown to improve the pig and poultry diet.

There was considerable variability in the data (Paper II) but the overall relationships supported the original hypothesis that the protein (N*6.25) content of duck weed can be manipulated by the addition of biodigester effluent

The present work suggests local breeds are better adapted to local environments and local resources and may out-perform the "improved" breeds under these circumstances.

The results of this preliminary trial with local pigs and their crosses (Paper II) fed a basal diet of sugar cane juice with duck weed as the only protein source indicated that the nutritive value of the duck weed was high in this particular feeding system, and superior to that of cassava leaf meal fed in combination with cassava root meal. Fifty percent of the Mong Cai pigs and their crosses with Large White were able to consume fresh duck weed in proportions sufficient to provide a diet with more than 10% of protein in the dry matter. Purebred exotic pigs (Large White) appeared to be less adapted to consume the duck weed and would only eat it when mixed with sugar cane juice, and even then with reluctance. Early exposure to duck weed may be an important factor in later acceptance of this feed.

The role played by livestock in farming systems for poor farmers is multi-faceted and synergistic and must be seen not as a primary form of production but rather in terms of its overall contribution to the total farming system and to the immediate needs of the family.

The wellbeing of poor farmers can be improved by bringing together the experiences and efforts of farmers, scientists, researchers and students from different countries with similar eco-sociological circumstances.

6. ACKNOWLEDGEMENTS

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Table 1. World Population Growth, 1950-1990, with projections to 2030

Year	Population (billion)	Population increase (billion)	Population growth per year (million)
1950	2.5		
1990	5.3	2.8	70
2030	8.9	3.6	90

Source: USDA 1992, cited by Brown & Kane 1994

Table 2: The biases in Indian agricultural research

Of all 1128 theses on all topics:
4.5% dealt with drought-prone areas
22 % dealt with rained agriculture
73.5% dealt with irrigated agriculture

Of 900 extension theses:
0.02% dealt with issues involving agricultural professionals and methods of science

Of 376 agronomy theses:
2% dealt with organic fertilizers and green manuring
27% dealt with inorganic fertilizers
11% dealt with irrigation
0.8% dealt with salinity
16% dealt with intercropping
18% dealt with millet and sorghum
30% dealt with cereals

Of the 329 sociology extension theses:
33% dealt with dry land regions
1.2% dealt with livestock
1% dealt with millets and sorghum
None dealt with pulses, fodder and forestry

Source: Gupta et al 1989

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Participatory Rural Development: Experiences in Binh Dien and Xuan Loc Villages in Central Vietnam

Lylian Rodríguez J[1] , Thomas R Preston[2] and Frands Dolberg[3]

ABSTRACT

In the past, especially in developing countries, research has been done mainly in experiment stations or universities, but the results have rarely been of benefit to the small scale farmer and often were detrimental in terms of impact on the environment. A more appropriate approach is to focus the research on the reality facing the small scale farmer and complement this with supporting problem-based experimentation in the experiment station and university.

This study was carried out in two villages in a rain-fed hilly region in Central Vietnam within a broad conceptual framework of sustainable development. The original idea of evaluating an intervention based on restricted milking of the local cattle was abandoned in the light of the insistence of the farmers that the expected benefits were too long term and they had other more immediate priorities

In contrast, discussions about the potential benefits from introducing low-cost biodigester technology were enthusiastically received, especially by the women. Over fifty biodigesters were installed in Xuan Loc and Binh Dien villages and around Hue city. Officials both of the People's Committee and the Women's Union took an active part in the programme and became "trainers" of other farmers, as well as "maintenance technicians", offering help to neighbours who had problems with their biodigesters. An evaluation of the impact of the intervention was made by the women farmers who had participated together with officials of local aid agencies. The result was a frank discussion of the problems and of the mistakes but with a final endorsement of the advantages of the technology. During the project activities there was concern on both sides (outsiders and villagers) about the follow up of the technology after the project ended. Therefore, the Women's Union in Binh Dien village developed a project proposal with the objective of securing development funds to ensure an extension of project activities, so that monitoring would continue of the biodigesters already installed and to facilitate the introduction of the technology in neighbouring villages. Visits by staff members of the Canadian Embassy were made to the village and the proposal was approved by the Embassy at the beginning

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of December 1995.
The traditional diet for pigs in the region was found to be lacking in protein (Nguyen Thi Loc et al 1996). Conventional protein supplements are only available in the market some distance away in Hue and are expensive. Biodigesters produce nitrogen-rich effluent and are a logical source of the required nutrients for growing duck weed as a local source of protein. Thus there was a potential connection between the biodigesters (being installed primarily as a source of fuel) and the need to improve the diet of the pigs.

As a result of the project activities and based on farmers' wishes research to document the local pig breeds became a priority. A survey was done to get some baseline data and a project was started at the end of August with 10 families, who were to receive one Mong Cai gilt per family.

In retrospect as the process of research unfolded, it had much in common with the participatory learning approach for sustainable agriculture described by Pretty (1995).

Key words: Vietnam; Women; On farm research; Low cost plastic biodigester; Extension; Effluent; Duck weed; Lemna; Integration; Ponds; Nitrogen; Protein;Indigenous breeds;Mong Cai; Energy.

INTRODUCTION

In the past, especially in developing countries, research has been done mostly in experimental stations or universities but the results have rarely been of benefit to the small scale farmer and often were detrimental in terms of impact on the environment. A more appropriate approach is to focus the research on the reality facing the small scale farmer and complement this with supporting problem-based experimentation in the experimental station and university.

Another problem is that excessive centralization and inflexible management tend to suffocate new initiatives. The reward systems for researchers are usually based on scientific publications which often discourages them from working in the field, where research is less controllable and the topics may be seen as less scientific. The analysis by Gupta and colleagues (1989) shows how this translates into a repeated focus on "modern" methods of farming and widespread ignorance of alternative resource-conserving technologies and practices.

On-farm research has many advantages. Farmers have always experimented to produce locally-adapted technologies, practices, crops and livestock (Chambers et al 1989; Brouwers 1993; Scoones and Thompson 1994). They are continuous adaptors of technology and their systems are rarely static from year to year. Richards (1989, 1992) has linked this process of adaptation to a performance, in which the actors change the nature of the performance according to the specific conditions. The problem is that researchers commonly do not understand or even accept that farmers can be "researchers". They assume that farmers are conservative and bound by tradition. Static and unchanging practices can therefore, upon investigation at a particular time, be characterized, analysed and so developed. But such an analysis can give nothing better than a snapshot of a complex and changing reality. It is important therefore, to begin to see technologies in a different light, not as fixed prescriptions but as indicators of what can be achieved. What agriculture needs is a willingness among professionals to learn from farmers, accordintg to Pretty (1995).

The "Farmers first and last model (FFL)" is an alternative to the transfer-of- technology model (TOT), and is based on farmers' perceptions and priorities rather than on the scientist's professional preferences, criteria and priorities. The starting point is the scientists learning from and understanding of the resources, needs and problems of the resource-poor farmers and the research stations and laboratories play a referral and consultancy role. This model is characterized by the use of informal survey methods, research and development within the farms and with the farmers and the final evaluation criteria is that a technology is adoption (Chambers and Ghildyal 1985).

Compared to a conventional experiment station approach to research, a farming systems research (FSR) approach is more comprehensive. It makes demands on skills beyond the capacity of the individual scientist and a team of scientists has to be formed, representing different disciplines (Dolberg 1990). For instance in this project the authors come from different backgrounds and have tried to learn and understand from social sciences by doing explorative research in the villages.

MATERIALS AND METHODS

The Research Site

The research was conducted from February to December 1995 in the Socialist Republic of Vietnam located in the Asia-Pacific region. Vietnam has an area of 329,560 km² and its population is over 70 million people. The criteria used to select the villages were:

- Binh Dien village has been involved since 1990 with a SIDA-SAREC research project so there was a mutual interest to carry out the work there. In addition, the MSc class was involved in an evaluation visit in 1994 and had installed two biodigesters, which created interest among the local people in this new technology.
- Xuan Loc village was selected despite it being a relatively new work area - but the Agriculture University of Hue was conducting a research project funded by IDRC, Canada.

Binh Dien Village

Binh Dien village is in the uplands in Huong Tra District in Thua Thien Hue Province in the central area of Vietnam. It is located 35 km to the south-west of Hue city.

Xuan Loc Village

Xuan Loc village is located in the uplands in Phu Loc District in Thua Thien Hue Province, to the south-west of Hue City (45 km distant).

Organizational System

The Socialist Republic of Vietnam is divided into 53 provinces. These are divided into Districts, the Districts into Villages or Communes and these are divided into Hamlets or Groups.

The villages have a strong organizational system. The main person in the village is the chairman of the People's Committee. A large number of organizations are involved in the People's Committee, such as the Communist party, the Police, a village military commander, Veteran's

Union, Farmer's Union, Women's Union, Youth Union, Finance group, Land office, Tax office and members from the Communication and Cultural offices.

General characteristics

Population

Table 1 shows the general characteristics in Xuan Loc and Binh Dien villages.

Binh Dien and Xuan Loc villages were established after the liberation and reunification of Vietnam (1975) and the people come from different areas and different backgrounds. In Xuan Loc there are people from different ethnic groups More than 77 % of the population belong to the lowland "Kinh group" that come from the coastal plain areas of Phu Loc District; 23 % belong to the "Van Kieu group", whose origin is Quang Tri Province where the main means of livelihood is shifting cultivation (Le Duc Ngoan et al 1995).

Land Distribution

Land distribution is shown in table 1 and the distribution of cultivated land is shown in table 3. In Binh Dien and Xuan Loc the forest is divided into natural forest and planted forest. In the case of Xuan Loc village about 45% of the land is occupied by natural forest (tropical rain forest) but day by day it has been reduced as a result of human activities such as extraction of firewood, timber wood, rattan, grass, etc. Further, there is a tobacco planting practice whereby forest is cleared every year for planting.

Animal population

The animal population in 1995 is shown in Table 4.

Climatic conditions

Both villages have the typical climatic conditions of the zone between the coastal plain area of central Vietnam and the Truong Son high mountain range. The data shown in Table 5 are from the nearest meteorological stations. In Figures 1 and 2 are shown the rainfall and temperature distribution.

It is possible to distinguish two seasons: the dry and the rainy season. The rain is concentrated mainly from September to December, when the temperature falls. Storms and floods are frequent in this period, which make the climatic conditions even more complex.

Water Resources

Drinking water is mainly from wells but also from the rivers, streams and springs. In Xuan Loc village about 10% of the households have deep wells.

Electricity

In Binh Dien village there are a few farmers (< 30) that have access to electric power from a hydroelectric scheme ,but only at certain times of the day and in the rainy season. In Xuan Loc village there is no electrical power, but one farmer uses a small generator. In both villages there is widespread use of motor car batteries for lighting and to run a radio and in a few cases a TV.

Education

In Binh Dien village there are 3 schools: a secondary school with 275 pupils, a primary school with 400 and a kindergarten with 175 pupils. In Xuan Loc there is only one elementary school (grades 1-5) and the nearest secondary school is 15 km from the centre of the village.

Health service

In Binh Dien there is a health centre (2 doctors, 2 nurses and 2 assistants) and a small hospital. In Xuan Loc there is only one small health centre.

As can be seen Binh Dien must be characterised as the better endowed village with regard to modern institutions and facilities.

OBJECTIVES

The overall objective of the research was to devise ways of making better use of the local resources. As it has been argued (Pretty 1995b) that the dominant positivist research paradigm has strong limitations when research is conducted in an open system like the on-farm situation, it was an important objective in terms of research strategy to test the farmer first and last model- FFL - (Chambers and Ghildyal 1985) and the participatory learning model (Pretty 1995) as applied to livestock research. The researchers' immediate objectives were:

- To understand the system of production in the selected hamlets and the role of the cattle in this system
- To study the possibility to establish a milk production programme to develop the "multi-purpose" (Preston and Leng 1987) use of the local cattle.

METHODOLOGY

The methods used were:

- The use of secondary information.
- Participatory work with the community.
- Feedback workshops with the farmers and the leaders of the community.
- As a result of the participatory work with the community to carry out on-farm research through appropriate interventions in accordance with each situation.
- To select a group of farmers to conduct the research in accordance with the community decision.

RESULTS AND DISCUSSION

Action programme

The field work started at the end of February 1995, but exploratory visits were made to both villages in 1994. Binh Dien was visited in August 1994 and Xuan Loc in November 1994 to introduce the researcher and to discuss possible ideas to develop in the future work. The initial aim was to understand the role of the local cattle in the system of production and the possibilities for initiation of a milk production programme. The first discussions with the members of the People's Committee and the Women's Union indicated there was interest in the development of new ideas.

Participatory work with the community such as visits, field work, workshops, informal meetings, and interviews were used during this study in order to obtain the confidence of the authorities and farmers and to exchange ideas and to develop the project. An interpreter was used most of the time because of the differences in language.

There was good support from the People's Committee and the Women's Union organizations in both villages but it was stronger in Binh Dien village. Some farmer leaders participated actively in the process and worked with the project to monitor and follow up the introduction of the new technologies.

Visits were made to the farmers who raise cattle and also farmers involved in a project in the use of ensiled cassava for fattening pigs (Nguyen Thi Loc et al 1996). After discussions with the village leaders it was agreed, as the first step, to set up biodigesters in the households of those farmers participating in the project as a contribution for their participation in the project and as pilot demonstration plants in each village.

The results are shown villagewise because the procedure and development of the project was quite different in both villages.

Xuan Loc Village

Biogas Digesters

During the first visit the possibility was discussed to build a small house for the project-researcher and the people's committee agreed. The University was given the responsibility for developing the idea with the community and to look for the cheapest and simplest way to build it. There were many aspects to take into account in order to take the decision of building the house in the village such as:

- there was an amount of money available for the lodging of the student
- the advantage of living and working in the village
- the most important being the possibility of developing a small scale integrated farm and start with the biodigesters.

Despite the fact that the community wanted to choose a different place, the house was built taking into account other aspects less important for the researcher and the project - factors that were outside the project control. At least one of the objectives was met, namely the demonstration of the potential for recycling manure. The biodigester was built the same day that the researcher took up residence and was functioning before the house was finally completed.

It was the biodigester that served as the real initiation of the technical/biological part of the project, since as soon as it began to function it became the centre of interest for the women in the village. Many people visited the house to see the biodigester to learn about it, and out of curiosity as well.

The SAREC MSC programme had another project in the village on the use of ensiled cassava root to feed pigs (Nguyen Thi Loc et al 1996). This project involved 12 families and credit was supplied from the project to buy 4 pigs and protein supplements for each family. In view of the interest in the biodigester technology, it was decided to install demonstration units in each of these households as a starting point to encourage participation by the community in project activities. The advantage of the low cost biodigester technology (Bui Xuan An et al 1996) is that the simplicity of the system facilitates maximum participation in the installation process - an ideal way of "learning by doing".

Thus the next step in project activities was the installation of biodigesters in ten households in the village. In the process of installation of the biodigesters, and the compilation of general data about the families (Table 6), there were opportunities to discuss with the families their ideas about the establishment of the milking programme with the local cattle.

The data summarized in Table 6 were collected before the start of the project. It can be seen that firewood is used not only for people. The feeds for pigs are traditionally cooked daily and it takes even more firewood than for satisfying the needs of the family. The data can be used to calculate that at least 1000 tonnes of firewood are used annually to cook the feed for the pigs and that 678 tonnes of firewood are used to cook for the 364 households in Xuan Loc village. One kg of firewood on average is worth from VND 200 to VND 300 (oportunity cost) which means that without the forest the villagers would have to spend between VND 340 to 500 millions (US$34 000 to 50 000) to buy fuel. In other words this is what the forest provides them free of cost today.

Establishment of a milk program with the local cattle

In addition to the general reaction to the idea of milk production, gained during the installation of the biodigesters, visits were made to several farmers who kept cattle as their major activity. The aim was to understand the system of cattle production in the village.

The local breed is almost 100% "Chinese yellow ", characterised by small body size (adult body weight of 180-200 kg), and light bone structure. As part of a genetic improvement programme, the Vietnamese government is promoting crossbreeding by supplying Red Sindhi semen to be used on local animals. Several of the richer families had purchased animals of the same cross (Yellow cattle x Red Sindhi).

Almost all the families in the village own some cattle (see Table 7) and as expected the richest people raised the largest numbers. The main purpose of raising cattle is for meat, manure for the crops and as a way to save money. Traditionally the management system is based on free grazing in the forest. Mainly it is the children who look after the cattle (when they go to school normally one goes in the morning and one goes in the afternoon) or sometimes a "cowboy" is hired to do this job. Every day the herd is taken to the forest for grazing and during the summer many farmers may keep the herd there for 2 weeks or a month according to the weather. In the rainy season, cattle are grazed near to the house because of the cool weather.

Cows usually have less than one calf/year weighing 7-10 kg at birth. The calves are suckled for 7 to 8 months by which time they may weigh 60 to 80 kg. After two years they can reach 180 kg. Natural mating is widespread in the village, as normally the cattle are kept together and there is no control. Some farmers that want to improve their cattle use artificial insemination (AI) obtaining semen from the station centre in Hue. One of the farmers is trained as an inseminator.

Most farmers have a simple pen where the cattle are kept at night time and during the rainy season. Supplementation is not common. Some farmers feed salt and some offer rice straw during the rainy season, and occasionally some cassava leaves when the harvest time comes, but generally there is no supplementation.

The idea of adding a new "purpose" for the local cattle was discussed. It was explained that to do this entailed some requirements such as: supplementation for the cow and the calf, some changes in the traditional management system "bringing the cow near to the house" and "separating the calf ". Fresh milk is not traditionally consumed in the family. When it is consumed it is in the condensed and sweetened form, usually taken with coffee. Even then, it is mainly reserved for old people, children and those who are ill. Nevertheless, there is "offer and demand" at local level, which means that it would be possible to start a local production programme at some time.

It is important to mention that in Hue there is a project promoting high yielding breeds such as Holstein with milk yields up to 15 litres daily, but with very hight inputs. Farmers in that project were visited in April 1995 and concern was expressed: "we can't recover the money that we invested in feeds". In fact the same 2 farmers belonging to that project were visited by the MSc course students in August 1994 and after 8 months (in April 1995) there were no more farmers involved. The "fresh milk shop" was visited as well where the price of milk was 4,000 VND per litre, and that illustrated that there is a market for fresh milk in Hue. These observations seem to support the assertion that "specialized livestock may produce less than local animals where the available feed resources are of low nutritive value and high energy and high protein concentrates are expensive" (Preston and Murgueitio 1994)..... in that situation.... multipurpose livestock offer advantages over specialized animals where the risks are attached to the production of a single product. This is one of the important reasons why dual purpose or multipurpose cattle are so common throughout Latin America (Sere and Vaccaro 1985; Vaccaro 1986). It seems valid to suggest these aspects must be taking in account for future developments.

Other aspects, which will need attention, are factors such as marketing and the way to preserve the milk according to the local conditions.

Finally, after carefully analysing the situation, the decision was taken not to go ahead.

Another important development arose in the process of installing the first biodigesters, as half of these were established in Binh Dien village (where the pig-cassava project was based). It became apparent that in this village there was more enthusiasm and participation. A second important decision (from the point of view of impact) was to work in both villages - in Binh Dien as well as in Xuan Loc. In fact, because of strong support from village leaders it was decided to concentrate most of the work in Binh Dien village.

The use of effluent from the biogas digesters to produce duck weed as a protein supplement for the traditional diet.

The traditional diet for pigs in the region was found to be lacking in protein (Nguyen Thi Loc et al 1996). Conventional protein supplements are only available in the market in Hue and are expensive. Duck weed can contain up to 40% protein in the dry matter when raised on fertilized ponds (Leng et al 1995) and can be grown almost anywhere in the tropics where there is water. Biodigesters produce nitrogen-rich effluent and are a logical source of the required nutrients for growing duck weed as a local source of protein. Thus there was a potential connection (see figure 3) between the biodigesters (being installed primarily as a source of fuel) and the need to improve the diet of the pigs.

This idea was enthusiastically received by the farmers , especially the women. And so, in Xuan

Loc, 10 families were selected through the Women's Union to join in this "pig" project which in turn was linked with the biodigester project. Funds were given to the Women's Union to develop a credit system for those ten farmers in order to buy the material to make the biodigester and to buy the pigs and to improve (or prepare) the pond to grow the duck weed. Later the money was to be repaid to the Women's Union to establish a revolving fund to give an opportunity for more women farmers to participate in these activities.

There was no experience in the village in the growing of aquatic plants. However, several farmers learned quickly how to grow them, and to keep them in good condition (fertilized with biodigester effluent), and also learned that the duck weed plants could be used as a high quality protein supplement not only for pigs, but also for ducks and chickens. The farmers appreciated that to introduce such a new technology implied a " learning process' which would take time and would not necessarily be suitable for everyone. Experiences in Colombia (Espinel 1994) showed that in such a process some farmer "leaders" will continue with the idea even after the project finishes and that others will realize the importance of the idea and eventually follow the example of the "leaders".

It became apparent during the development of the "duck weed" project that there were many factors which influenced duck weed production - some controllable and others determined by climatic conditions (flooding!). Management was found to be the most important factor - eg: the levels of effluent to be used, water exchange and the need to renew the seed. Very little was known on the use of the biodigester effluent to produce duck weed, so this aspect was a logical subject for "on-station" research (Paper II). Some of the results on the yield of duck weed at farmer level are shown in Figure 4.

The role of leaders and local organizations in "on farm research" and technology transfer

Close collaboration, confidence and "clarity" between researchers, advisors and local leaders, institutions and organizations are fundamental for successful "on-farm research and technology adaptation". There are many factors affecting the process, especially when an "outsider" comes to the village with some ideas but little understanding of the real situation, or even more important when there are cultural and language differences between the outsider and the target group. In Vietnam, where "local" organization is very developed, leaders and organizations such as the Women's Union's can move masses and thus activate the process. Equally they can "stop it" and then there is no impact. There are many internal (in the village) factors affecting the role of these institutions, such as lack of communication among organizations, competition for power, self interest and created interests - all of which can make the situation even more complex and will affect the work environment.

Binh Dien Village

Biogas Digesters

The biodigester project in Binh Dien was the same as in Xuan Loc. It was a component of the SIDA-SAREC MSC Course project on the use of ensiled cassava to feed pigs (Nguyen Thi Loc et al 1996). There were 12 families and credit was supplied from the project through the Women's Union to buy 4 pigs and protein supplements. The materials for the biodigesters were donated as it was considered they would be used as a demonstration of this new technology. It was also a way of compensating the farmers for taking on the role of "researchers", doing the extra work in keeping records, controlling the feeds and generally carrying out many of the functions which in the research station would be done by professional technicians. Throughout the process, emphasis was on "participation" that can be classified according to Pretty (1995, p.173) as "interactive participation"- in installation of biodigesters, evaluating the results, providing feedback, discussing adjustments to the technologies and, always, "learning by doing" was the basic philosophy. Data on the families in the Binh Dien component of the project are in Table 8.

In Binh Dien village there was a very strong participation by the Women's Union, the leaders of the People's Committee and some farmers who, from the beginning, made the process more dynamic and by their enthusiasm facilitated the feedback between the target group and the project, thus enriching the work in this village.

Establishment of a milk programme with the local cattle

Visits were made to several farms to survey the system of cattle production in the village. The cattle population is shown in Table 9. Distribution was less equitable than in Xuan Loc, as cattle numbers increased much more rapidly among the wealthier families.

The management was the same as in Xuan Loc but in this case there were some farmers interested to try to start the project. Workshops were held to discuss with the farmers and leaders possible ways to begin the project. The proposal was to use a supplement of rice straw treated with urea (that has been shown as successful technology in China and Bangladesh, Dolberg et al 1995) with some tree leaves (eg: from the Jack fruit tree) for cow and calf and some additional rice bran for the cow. A group of farmers that had 1 or 2 cows recently calved agreed to build a simple place to milk the cow and a pen to keep the calf away from the cow. Several farmers milked the cows but the yield was too low - only 50 to 100 ml in the first days. Discussions were held with the Women's Union and farmers and many factors were analysed. Finally there was a meeting to decide the following step, and the farmers gave the following reasons for stopping the project:

- It was a very new technology for them
- There is no tradition to milk the cows
- The traditional management is so easy and milking the cows makes the management complicated, especially working with only one or two cows from the herd
- Marketing still a big constraint.
- The production of local cows appears to be very low
- There are priorities that can generate better results and have more effect on the family
- In the future it could be good idea to be developed but maybe it is not the right time

And also discussions were held on the subject of "how did they want to work and invest their efforts?" and the following points were made:

- Pig production is a very important source of income in the family
- There are many problems to buy the weaner piglets for fattening and also if they are available they can bring many problems/diseases to the village, so improving breeding sows could be a good project because we only have around 20 sows in the village.
- The local "Mong Cai" is the right breed to use because it has a very good reproduction, produces many piglets and is well accustomed to use local resources such as "green plants".

- The Mong Cai sows can be crossed with "white" (improved) boars to produce crossbred pigs for fattening.

Research to document production traits of the local breeds became a priority. A survey was done to get some baseline data and a project was started at the end of August with 10 families, who were to receive one Mong Cai gilt per family. It took the Women's Union a long time to buy the right breed, because it is becoming more difficult to find "pure" or at least a "high grade" gilts of the Mong Cai breed. The last family to get a gilt received it in November 1995. The Women's Union agreed to be responsible for supervising the follow up of the project and to collect the data on the reproductive performance of the Mong Cai sows. The farmers will repay the credit and the Women's Union will manage it as a revolving fund to get more farmers involved in this project.

The use of effluent from the biogas digesters to produce duck weed as protein supplement for the traditional diet

The comments made under this heading in the Xuan Loc project are equally applicable to Binh Dien, and will not be repeated here.

The role of leaders and organizations in "on farm research" and technology transfer

The chairman of the village, the leaders of the People's Committee and the Women's Union especially, were actively involved in the development of the project, in providing new ideas, adopting and adapting the technologies, questioning the researcher's ideas and were concerned for the continuity of the project and not only for their own development but also for the development of surrounding villages. This experience confirms how important is the close collaboration, confidence and "clarity" between researchers, advisors and local leaders, institutions and organizations.

Introduction of new ideas to farmers outside the project and other villages

In Binh Dien village where the process was more active the Women's Union took the initiative to introduce the biodigesters, duck weed and cassava ensilage to other villages, so there was a meeting with more than 60 women from the 15 villages belonging Huong Tra District where women leaders from Binh Dien Village, the researchers (Nguyen Thi Loc and Lylian Rodriguez), one of the advisors (T R Preston) and the principal researcher in the biodigester project in Vietnam (Bui Xuan An) were together to share the experiences during the process of establishing the project in Binh Dien village and other places in Vietnam.

Low cost plastic biogasdigester in Binh Dien and Xuan Loc villages

Background

Energy is a fundamental factor for economic development, but normally the energetic models are based on "non-renewable resources". There are many kinds of energy such as:

- Hydraulic energy
- Wind energy
- Solar radiation
- Biomass (through pyrolisis and gasification)

During the course of this century the world energy consumption /inhabitant has grown 16 times. Today the industrial countries with 32% of the world population consume 82% of the planet's energy. On average, a person from an industrialized country consumes 20 times more energy than a person in Africa. It is clear that the "economic development model" is what drives energy consumption.

In many developing countries there is a serious shortage of fuel and the energy crisis is a daily reality for most families. Cooking is one of the most energy-consuming activities, yet is often inefficient. The open fire is still very common. Today the devastation of forest in developing countries is frequently mentioned in the mass media. The forests in Africa, Asia and Latin America are disappearing and the desert is advancing in its place with serious consequences. Deforestation has many causes. Poor people are migrating and inhabiting, cultivating and using new forest areas. In some areas they use "slash and burn" methods and this is another factor rapidly depleting the forest areas. War has been another important cause of deforestation. However, the daily consumption of fuel (Tables 6 and 8) must not be underestimated when considering causes of deforestation. It is not unusual for a family to have to spend the greater part of their day gathering fuel for their home. At times dozens of kilometres need to be covered to find fuel (Nystrom 1988).

Facing this situation the use of renewable energy sources like solar energy for lighting and low cost plastic biodigesters to give an efficient use of the manure in the farming system to produce gas for cooking and effluent to fertilize ponds for fish, aquatic plants and crops will bring advantages to the family and to the environment.

Low cost biodigesters in Binh Dien and Xuan Loc villages

The objectives of the biodigester programmes in developing countries should be to establish minimum cost systems, using only local materials and with a simple technology so that farmers themselves can readily learn to install and manage the biodigesters (see Figure 5). To this end it was decided to use a continuous-flow flexible tube biodigester based on the "Taiwan" model as described by Pound et al (1981) and later simplified by Preston and co-workers first in Ethiopia (Preston 1985, unpublished data), in Colombia (Botero and Preston 1986) and later in Viet Nam (Bui Xuan An et al 1993).

In Binh Dien and Xuan Loc villages, more than 50 biogas digesters were installed as part of the project activities, with an average cost (for materials) of US$29.00, including two burners (see Table 10).

Gas production was measured using a Japanese gas flow meter (model number: K875-/YAZAKI KEIKI Company) which was installed on a rotational basis in the households of 16 families. The results are shown in Figure 6. The inputs (manure and water) and outputs (effluent) were recorded (see Table 11). The data showed a significative difference ($p=0.000$) in the proportion of water/ manure used to load the biodigester between the two villages. In fact the difference is in the amount of manure used to load the biodigester, but not in the amount of water and it is because the availability of cow manure is higher in Xuan Loc than in Binh Dien village. The difference in gas production per kg of DM can be attributed to the fact that, in Binh Dien, farmers use mainly pig manure. There is also the fact that latrines were linked with the biodigester when the gas production was measured in Binh Dien village. However, there are not enough data to draw firm conclusions on this aspect, and further research is needed. However, according to the literature the data are reliable, because the gas production per kg of DM of manure should be around 150 litres (Bui Xuan An et al 1996).

Analyses of N content, Chemical Oxygen Demand (COD) and colonies of *E. coli* were made for the material loaded and effluent in 20 biodigesters. The results are shown in Table 12 and the effect in the reduction of COD and *E.coli* is clear. McGarry and Stainforth (1978) showed that by recycling human and animal wastes in biodigesters at internal temperature of 30-35°C, it is possible to destroy up to 95% of the eggs of parasites and almost all the bacteria and protozoa that cause gastrointestinal diseases.

For N content the data are not reliable, because it would be expected that the content of N in the DM of the effluent is higher than in the input manure. It is important to mention this point because it highlights the difficulties of obtaining reliable data when the samples are just sent to a laboratory to be analysed , and it shows the need for the researcher to do her/his own analysis.

Stoves

The biodigester plant includes a simple stove made with galvanized pipe of 21 mm internal diameter. It has two burners made with the same sort of pipe and two ball tabs with the same diameter. It seems to work quite well but it can be improved. Measurements were taken fitting the gas metre between the storage bag and the stove and the results were on average that in 1 hour it is possible to boil 6 litres of water and the amount of gas used is 26 litres/litre of water, in other words 156 litres/hour which agrees with the literature (150 litres of gas per hour (CVC et al 1987, Botero and Preston 1986). The farmers developed many ideas to avoid the effects of wind and to have a more convenient place to put the pans. Each farmer had different ideas and those that improved the stoves said that they were much better. In fact a lot of research has been done on improved stoves for firewood, charcoal and others sorts of fuel, but only a little on stoves for low cost plastic biodigesters. In India a study was carried out among user populations and it was found that the fuel saving range is from 32 to 42% using the improved stoves (Ramachandra 1994).

Latrines linked with the biodigester

The leader of the Women's Union from Binh Dien village visited the project in Xuan Loc where the project house was built and immediately appreciated the significance of having a toilet connected with the biodigester system. She returned to Binh Dien convinced of the advantages of developing the idea in her own village. A credit system was therefore organized through the Women's Union to establish toilets as components of the biodigesters in families already participating in the biodigester project.

Follow up work

Over 50 biogas digesters were installed during the project of which 20 were donated for the project (10 per village) to farmers involved in Nguyen Thi Loc's project and the 30 left were financed through a credit system from the Women's Union. All the money used for the project was given to the Women's Union and they developed a credit system to work with the farmers with the idea to use the money in a revolving research fund (Solarte et al 1994) thereby giving the opportunity to more farmers to participate in such projects in the future.

During the project activities there was concern on both sides (outsiders and villagers) about the follow up of the technology after the project ended. Therefore, the Women's Union developed a proposal (see Annex 1) and presented it to the representative of CIDA (Canadian International Development Agency). The objective of the proposal was to secure development funds to ensure an extension of project activities, so that monitoring would continue of the biodigesters already installed and to facilitate the introduction of the technology in neighbouring villages. Visits by staff members of the Canadian Embassy were made to the village and the proposal was approved by the Embassy at the beginning of December 1995.

In fact there are many technical and non-technical aspects that must be included in the "follow up" of the project such as:

- Technical aspects: proportion of water and manure to be loaded
- Proportion of pig and cattle manure
- Gas production in the dry and the wet season
- Different uses of effluent to water and fertilize trees, crops, and fish and to produce water plants as a source of protein
- Installation procedures (to link the pig pen, latrine, biodigester), the width of the trench for specific kinds of soils
- Effect of linking latrines with the biodigesters
- Management and maintenance: fence, shade or not?
- Durability of the plastic
- Stoves' design

In the introduction of the technology:

- How to introduce the technology to a new area?
- Which aspects to take into account to introduce the technology to a new area?
- Who are the right people to start?
- Technicians attitude
- Credit systems for the poor.
- Is the biodigester suitable for the poorest?

Evaluation of the project in Binh Dien and Xuan Loc Villages

At the end of the project a meeting was held with the village leaders and farmers to evaluate the results of the year's activities. The aim was to identify and discuss the problems and the benefits, and to plan future activities. The outcome of the evaluation is summarized below:

Binh Dien Village

The farmers' thinking shows the reality in the village. In Binh Dien many families have to buy firewood because the forest is far from their houses or because there is not enough labour in their families, so the benefit that they can get from the biodigester is very important. However, there are also many farmers whose only source of income is from the forest, cutting firewood for their families and selling at village level or in the city. There is a clear understanding of their situation and the comments reflect their observations and they show many aspects that need to be improved in a "practical way" and which can be subjects for further research.

A very important aspect illustrated in Table 13 is the "lack of manure in poor farms". This is where the biodigester can be important, but not as a means to "start" to improve the standard of living because very poor farmers have other priorities and the strategy must be different to improve their conditions. The value of effluent to water the trees or vegetables in the home garden or to produce aquatic plants such as duck weed is appreciated.

At the end of the project 25 biodigesters were visited , of which 68 % were in good condition and 32% had problems or were not working. The reasons were: 12 % had problems because of accidents (especially animals that fall into the trench), 8% due to problems at installation, 8 % because of management or lack of manure and 4 % (i.e. one) was destroyed due to flooding.

In Table 14 the farmers' reaction to the introduction of a new plant "duck weed" as a source of protein in the village is shown. In fact several farmers having biodigesters, but outside the project, started to grow duck weed because they were aware of its high nutritive value for their animals, not only for pigs, but ducks and chickens as well. It is important to mention that traditionally duck weed is sold at the market in Hue.

In Binh Dien village after the decision to "not go ahead" with the "milk program" there was a project with the indigenous breed Mong Cai. The farmers, therefore, also discussed some benefits, problems and future activities in that regard (Table 15).

Xuan Loc Village

The results of the evaluation are shown in Table 16.

In Xuan Loc the situation was quite different and there were many factors to be analysed:

- There is plenty of forest and it is one of the main sources of people's sustenance.
- Living conditions are not as good as in Xuan Loc, which means that maybe biodigesters are a suitable technology for some part of the population, but for the very poor people a strategy must be developed in order to improve their standard of living before biodigesters have a role to play.
- There was less participation in this village during the project and less enthusiasm from the leaders. Although the leader of the Women's Union was very active there was no strong support from the People's Committee.
- Climatic conditions are a constraint, because floods can wash away biodigesters . In reality only one biodigester was destroyed during the wet season, but the possibility must be considered when people choose the site to setup the pig pen and biodigester. However, this is a risk not only for the biodigester.

At the end of the project 20 biodigesters were visited and 60 % were in good condition, while 40% had problems or were not working. The reasons were: 10 % had problems because of accidents (specially animals that fall on them), 10% because they had problems at installation, 15 % because of poor management or lack of manure and 5 % (which means one) were destroyed by a flood.

After the evaluation a workshop was held (funded by FAO) in both villages to give some practical recommendations about biodigesters and introduce another protein resource for livestock: (a tree - *Trichanthera gigantea*) that has given good results in Colombia and in the South and North of Vietnam. See Annex 2 for workshop report.

Survey on Mong Cai sow performance in Binh Dien Village

Background

The population of local breeds of livestock is steadily decreasing due to lack of infrastructure and of economic incentive to encourage access to, and use of, this genetic material for breeding. To date, almost all efforts have been directed towards the introduction of "improved" and "new" breeds with very high genetic quality but with an equal dependence on high inputs and with poor adaptability to "less than ideal" conditions which are the "norm" in rural areas of most developing countries.

In Binh Dien village, pig production plays an important role in the farming system but there is a shortage of piglets which brings many problems for the village because farmers have to buy the piglets in different places. The problems include:

- Disease transmission
- Poor quality (bad health, poor development, infections)
- High price (many middlemen!)

In the village there are around 20 families that raise sows for breeding, but annually farmers in the village require to fatten upwards of 1000 pigs. It is evident that there is a place to develop a larger population of breeding sows. For this reasons a survey was done in order to understand the traditional management system, the breed used and its performance. Sixteen families were interviewed and the following information was obtained:

Breeds

In Binh Dien there is a long history of using local breeds for reproduction purposes, principally the Mong Cai or Cornwall ("not local breed", but well adapted because it has existed for many years in Vietnam (Molenat et al 1991). Despite this, the Government in 1994 established a policy that: "farmers are not allowed to use the Cornwall breed".

The Mong Cai breed is important for breeding but the males have a very low price, which makes it difficult for farmers to keep the pure breed as the demand is only for females. Thirteen families had a history of raising Mong Cai sows. Performance parameters are summarized in Table 18.

In Figure 7 the litter size at birth and weaning for Mong Cai sows in 13 familiesis shown, and in Figure 8 the longevity and prolificacy. The farrowing interval and open days are shown in Figure 9 and in Figure 10 the weaning weight for Mong Cai crosses. The data show a very good picture of the reproductive performance of Mong Cai sows, which compare well with typical performance traits that are obtained in commercial farms with breeds of high genetic merit and feeds of high nutrient density. For instance the farrowing interval, which is a good measure of the reproductive performance, is 181 days, while in high quality breeds it is of the order of 175 days (Sarria et al 1994). However, in the latter case, the conditions are very different. Mortality to weaning in "high tech" systems can be high - upwards of 10% , while in the baseline data for the Mong Cai the mortality to weaning is less than 10%.

Housing

The management is very simple. Often the pig pen is an open one with enough space to keep the sow and the piglets comfortably. Most farmers use a packed clay-floor, while a few have a partially concreted floor and a part packed-clay floor. Some farmers have a fence around the pen, often a "live" fence of cassava or bamboo, so as to restrict the area in which the piglets can scavenge. The emphasis is usually on some form of housing which is cheap and yet comfortable for the sow and her litter.

Feeding System

Farmers use the traditional locally available resources to feed the sows. The results of the survey are shown in Table 19. Farmers treat their sows as "people" in Vietnam, where sticky rice is used for celebrations or special occasions, and yet in Table 19 is it shown how farmers feed some sticky rice, green beans or eggs when the sows have farrowed or some days before - however, is important to make clear that the amounts that are fed are very low. For example: 1 egg per 3 days or 100 g of green beans per day the first week after farrowing.

In general, farmers try to provide some protein-rich supplement in order to keep the lactating sow in good condition. However the amount is very limited and in general the feeding system is according to the cropping season and the family situation. The interesting point to make is the adaptation and good performance of the Mong Cai sows under relatively poor conditions of nutrition and management.

Some farmers use specific strategies, such as after the weaning waiting for two heats before mating, which gives some time for the sow to recover its body condition.

Breeding System

Artificial insemination is a common practice in this village. Farmers can obtain semen from an insemination centre in Hue city and they have learned how to inseminate . It is a very effective and cheap system, and in the village boars are not available.

In the Department of Agriculture of Thua Thien-Hue, Mr Nguyen Viet Dan (personal communication) explained that the Vietnamese government has the plan to destroy the breeds that have very low production , including "some of the local breeds". In 1975 Mong Cai pigs were brought from Tam Dao, Quang Ninh, and Hai Phong Provinces in the north, and 300 Mong Cai sows for breeding purpose were taken to a state farm. However, in 1980 this farm collapsed and some of the sows were given to the farmers. There are no statistics about the number of animals in Hue Province but it has still a very low population. Actually the government plan is to keep the Mong Cai for breeding and to cross it with an exotic breed such as Large White for fattening but the problem is availability of semen because in the province there are only 3 "insemination centres" (farms!) that will be describes below:

- Namgia (Hue city): State farm, 7 Large White boars and a young Mong Cai (not yet mature) boar. 40 doses of Large white (VND 6000/dose) semen per day are distributed to 4 workers in 4 districts (Phu Loc, Thuan An, An Lo and Bao Vinh). The veterinarian or farmer learn how to do the insemination at village level.
- Nguyen Hau (Quang Phuoc village, Tam Gian Lagoon) is a farm owned by the Agricultural Department but rented and administered by a farmer from this village. 25 doses are available per day, but there is no Mong Cai Semen. However the farmer raises 3 Mong Cai sows and is planning to have a Mong Cai boar.
- Van Huu Nguyen is a private farm with several Yorkshire and 1 Mong Cai boar. There is semen available but according to the farmer almost all Thua Tien Hue province depend on this Mong Cai boar and some other provinces also. The availability of Mong Cai semen is very low: only 2 doses each 3 days and the prices are VND 8,000 per Mong Cai and VND 4,000 per dose of Yorkshire semen. There is a big

demand for Mong Cai semen in his village and in general in the province and other provinces.

It is evident that there is need to develop simple centres at village level to increase the population of the Mong Cai breed. This local breed has very good reproductive performance and is well adapted to the local conditions and local resources.

Observations at village level about the efficiency of the Mong Cai breed in the use of local resources were the motivation for carrying out an "on-station experiment" to explore the digestion parameters and N metabolism of Mong Cai and exotic breeds and their crosses (Paper III).

Factors that interact in "on farm research" and "on station research"

Research on behalf of developing countries has been done ostensibly with the objective "to improve the standard of living of people". Unfortunately, much of the research in the industrial countries is irrelevant and may even result in the destruction of local cultures and self-reliance through exports of inappropriate technologies.

Research and development activities must be viewed in the perspective of interactions, the most important of which is that between "imported technology" and the local situation. Leng (1995) has shown very clearly how many components interact to influence overall performance of ruminants on a specific diet. In the laboratory, with controlled conditions, one of the characteristics of feeds, such as digestibility, often has the greatest impact on animal productivity, but this is not the case in most field situations.

According to our experience in this project this interaction can be demonstrated in Figure 11 where on farm research or much better the "participatory learning process" (Pretty, 1995b) is the starting point to get a clear understanding of the situation and to define research priorities. However, there are many interacting factors, such as:

- Human factors, such as the attitudes of the outsiders and the target group: culture, communication and attitude are essential factors that can stop or makes the process work.
- Environmental factors such as rainfall distribution, temperature, storms and floods will affect the results and lead some scientists to decline undertaking "on-farm" research, but they will then miss the reality.
- Technical aspects such as: communication with other scientists working in the same way, facilities to get relevant information/references and more specific aspects such as laboratory facilities that are a constraint in developing countries. Knowledge of their existence may lead the researchers to allocate them a higher priority than they deserve in order to obtain reliable data. But the other side of the coin is, what is the meaning of reliable data produced out of context?
- Economic resources such as access to adequate credit, which is also one of the main constraints because it is not available and the knowledge (Hashemi, 1996) about it is very weak in both outsiders and in the target groups, contributing to the complexity of a solution.
- Feed resources (availability, quality, prices)
- Animals (health conditions, breeds, age)

- Water (quality, availability) - for example for biodigesters water is an important resource.
- Soil (type, fertility)

These aspects are interacting positively or negatively in the process. However, the experiences of the present work lead us to conclude that these issues are best addressed within a framework of FFL and learning approaches, where the research starts in the villages and the station and the laboratories play referal and consultancy roles.

What is the way ahead?

At the beginning of the document data were shown about the animal population in Binh Dien and Xuan Loc villages, but based on the insights we have now gained it is important to think deeply about some aspects such as the change of the animal population in both villages through time. In Figures 12 and 13 data are shown on animal numbers from 1989 till 1994 and it is evident that animal production plays a important role in these two villages. It seems that the cattle numbers are increasing very fast in Xuan Loc village, mainly through grazing in the forest, and therefore at the expense of the environment.

There is not much difference in the development in pig numbers over time, but there are clearly more poultry in Binh Dien, probably reflecting the village's better access to the market, making it easier to sell poultry products.

In Table 20 and 21 data are shown on the distribution of cattle and pigs according to wealth ranking of the households. There are no data on poultry distribution in the village, but according to our observations poultry is especially important for the poorest people, because poultry need much less capital than pigs and cattle.

The data confirm that cattle are mainly in the hands of the wealthiest people, while the pigs are more equally distributed. Thus in Xuan Loc village in 1994 of a total cattle population of 1453 animals 1210 or 83% were owned by 39% of the households categorized as poor and better off. The 61% very poor households had 17% of the cattle. With regard to pigs, the situation is less biased. In 1994 19% of the pigs belonged to the 9% better off households, but 47% to the 30% poor households and 33% of the pigs to the 61% very poor households.
The same broad picture with regard to ownership of animals by wealth ranking of households can be seen in Bien Dinh village. However it is interesting that in this village the majority of pigs are owned by the very poor households.

At this point it is pertinent - in a context of self criticism - to point out that most animal production research in developing countries has been on large ruminants and within large ruminants on crossbred milking cows. We considered ourselves to be advanced in relation to that situation by initially wanting to do research on the local cattle, exploring the potential of adding another (milking) purpose to their uses in support of the general idea of multipurpose cattle being more appropriate (Preston and Leng, 1987). However, the data in Tables 20 and 21 clearly show that had we stuck to this original idea, we would only have done research for the wealthier sections of the villages and hardly touched on problems of relevance for the poor and the environment, as the poor live off the environment to a great degree.

We overlooked poultry, and there is recent evidence that species such as poultry needs further research. Ongoing work in Bangladesh shows that properly designed poultry projects (Saleque A and Mustafa S 1996, Askov Jensen H 1996, Nielsen H 1996) have a potential to reach the poorest in a village that even Grameen Bank type loans do not have (Hashemi, personal communication).

CONCLUSIONS

We have found it fruitful to apply a participatory approach in this research. If there is true participation the real necessities can be highlighted and new ideas can be developed and allowed to influence the research. Participation is a mutual learning process where "outsiders", local authorities and farmers can increase their awareness of what to do to achieve change. But what is true participation? There are many kinds of participation from passive participation, where people are involved merely by being told what is to happen, to self-mobilization, where people take initiatives independent of external institutions (Pretty 1995). Through the project activities it has been shown that participation is also a learning process, based principally on confidence among outsiders and the target group.

On-farm research is a dynamic process. Farmers have always experimented to produce locally-adapted technologies. Farmers are often excellent "researchers" and "extensionists". In this way, research and extension go together, which is the best approach. When the research is done on-farm the process can be faster and there is a "natural selection" of technologies and priorities - and therefore there can be less waste of time and money. Applied in this way the "Farmers first and last model (FFL)" is an alternative to the transfer-of- technology model (TOT), and is based on farmers' perceptions and priorities rather than on the scientist's professional preferences, criteria and priorities.

In this project there was a clear example of how we "outsiders" (Chambers, 1983) think about "appropriate technologies" to be applied at village level. The result was a "learning" from farmers and the project changed direction - from milk production as an additional purpose for the local cows to biodigesters to duck weed as a source of protein, to local breeds of pigs and, finally, to get an overall view of the socio-economic situation of the village. Clearly it is a means of really, but not completely, understanding the village situation. There must be an active process where outsiders try to understand the situation, offer alternatives which may have some impact in the village, using an iterative process of trial-and-error (Dolberg, 1994) in which villagers participate actively by making criticisms and suggestions to the outsiders and giving ideas which may change the researcher's objectives. The starting point must be around this approach, and it can not be achieved only with participation in information giving (Pretty 1995) where people participate by answering questions posed by extractive researchers using questionnaire surveys or similar approaches and people do not have the opportunity to influence proceedings. What agriculture needs is a willingness among professionals to learn from farmers.

Close collaboration and confidence between researchers, advisors and local leaders, institutions and organizations are important preconditions for successful "on-farm research and technology adaptation". There are many factors affecting the process specially when an "outsider" comes to the village with some ideas, but little understanding of the real situation or even more important, when there are cultural and language differences between the outsider and the target group. In Vietnam, where the "local" organization is very developed, leaders and organizations such as the Women's Union's can move masses and thus activate the process. Equally they can stop it and then there is no impact. There are many internal (in the village) factors affecting the role of these institutions such as lack of communication among organizations, competition for power, self interest and created interests - all of which can make the situation even more complex and will affect the work environment.

In some respects, especially when new technologies are being developed or adapted, it is advantageous if on-farm research is complemented with "on station" research. But there must be a clear understanding of, and link with, the reality of the farmer situation.

Milk production as another "purpose" for the local cattle may have a potential. However, it may not be a first priority. Very few very poor people keep cattle, but they live off the environment by collecting and selling firewood. More work with pigs and poultry and appropriate credit arrangements are more likely to benefit them and thereby the environment.

Biodigesters can play a pivotal role in integrated farming systems by facilitating control of pollution and at the same time adding value to livestock excreta through production of biogas and improved nutrient status of the effluent as fertilizer for ponds and crop land.

Biodigester impact is variable, adoption and successful results depend on aspects such as location (availability of fuel), the way in which the technology is introduced, supported, adapted and improved according to the local conditions, and the technicians' attitudes.

Traditional diets for pigs lack protein and conventional protein supplements are expensive or are not available. Therefore when the biodigester is part of the system, producing gas and effluent rich in nitrogen, duck weed can be grown to improve the pig and poultry diet.

The present work suggests local breeds are better adapted to local environments and local resources and may out-perform the "improved" breeds under these circumstances.

Further research is needed in aspects such as:

- The role of poultry in the farming system for the poorest people
- Comparison of local and exotic pig breeds in the context of integrated farming systems.
- The way to introduce the biodigester technology in different social and ecologic conditions.
- Technical aspects of low cost plastic biodigesters: use of effluent as fertilizer, stoves for low cost plastic biodigesters, effect of use of latrines.

These factors are based on farmers' ideas and experiences. They are not the researcher's ideas, or they have become so after a learning process at village level. However, sources of protein for livestock such as aquatic plants and tree leaves should be added to the list of future research topics.

The role played by livestock in farming systems for poor farmers is multi-faceted and synergistic and must be seen not as a primary form of production but rather in terms of its overall contribution to the total farming system and to the immediate needs of the family.

Following this exposure, we argue that integrated farming systems offer unique opportunities for maintaining and extending biodiversity. This is an area deserving much more research. However, as shown in the paper "Context influences content" (Gupta, personal communication) it is clearly very important to conduct the comparisons in typical contexts (on-farm) with typical feeds (those farmers use).

The wellbeing of poor farmers can be improved by bringing together the experiences and efforts of farmers, scientists, researchers, and students from different countries with similar eco-sociological circumstances.

Learning by all (scientists and farmers) is a fundamental issue: Are we new professionals prepared to work according to this approach?

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Table 1. General characteristics of Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc
Population	2,957	1,990
Households	557	364
Members/family	5.30	5.46

Source: Binh Dien and Xuan Loc villages, 1995

Table 2. Land distribution in Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc
Total area, ha	**2,498**	**4,236**
-Forest, ha	1,796	2,739
-Grassland, ha	300	1,231
-Agricultural land, ha	402	266
*Cultivated area, ha	127	140

Source: Binh Dien and Xuan Loc villages, 1995

Table 3. Cultivated land distribution in Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc
Cultivated area, ha	**127**	**140**
Sugar cane	25	0
Rice	7.5	50
Cassava	41	75
Sweet potato	40.5	15
Vegetables, groundnuts	13	nd

Source: Binh Dien and Xuan Loc villages, 1995; nd: No data

Table 4. Animal population 1995 in Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc
Pigs	1,200	1,056
Cattle	800	1,281
Buffalo	49	81
Goats	10	0
Ducks	450	nd

Source: Binh Dien and Xuan Loc villages, 1995; nd: no data

Table 5. Climatic conditions in Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc
Altitude, masl	30	50
Temperature, °C	13-29	20-28.7
Relative humidity, %	80-85	78-92
Rainfall, mm/year	2,021	2,681

Source: Forecast Station Service - Thua Thien Hue Province, 1995

Table 6. General information of families involved in Xuan Loc biodigesters project

	Average	SE
Family size	5.6	±0.6
No. children	3.1	±0.6
Biodigester		
Length, m	10.0	±0.0
Total volume, m^3	5.4	±0.0
Distance digester-kitchen, m	9.0	±1.2
No. burners	2	±0
No. animals		
- Sows	0.7	±0.2
- Piglets	1	±0.7
- Fattening Pigs	5.1	±0.7
- Cattle	10.4	±2.5
- Buffaloes	0.7	±0.5
Firewood for people/day, kg	5.1	±0.5
Firewood for pigs/day, kg	7.6	±0.8

Table 7. Cattle population according to wealth categories in Xuan Loc village

	Very poor	Poor	Better-off
No. households	222	109	33
Households having cattle or buffaloes (%)	63	95	93
No.of cattle/buffalo/households	2-4	5-6	10-12

Source:Le Duc Ngoan et al, 1995

Table 8. General information of families involved in Binh Dien biodigesters project

	Average	SE
Family size	4.9	±0.33
No. Children	2.7	±0.34
Biogasdigester length	9.7	±0.28
m^3 liquid vol	5.63	±0.16
Distance Digester-Kitchen	9.8	±1.06
No. Burners	2	±0
No. Animals		
- Sows	0.1	±0.094
- Piglets	0	±0
- Fattening Pigs	3.5	±0.62
- Cattle	3	±2.638
- Buffalos	0.1	±0.094
Firewood for people, kg	7.1	±1.226
Firewood for pigs, kg	8.3	±1.239

Table 9. Cattle population according to wealth categories in Binh Dien village

	Poor		Medium		Better-off		
	1990	1994	1990	1994	1990	1994	
No.of households	225	237	60	165	15	55	
% households having cattle		0	3	40	30	60	55
No.of cattle	0	40	30	360	70	300	

Source:Binh Dien Village, 1995

Table 10. Cost of a plastic biogas digester in Hue-Vietnam

	VND/Unit	Units/digester	Total
Plastic+transport HCMC-Hue	208,000	1	208,000
Transp Hue-Xuan Loc/Binh Dien	13,500	1	13,500
Ceramic Pipes (100 mm)	11,000	2	22,000
PVC Elbows (21 mm id)	800	3	2,400
PVC pipe (21 mm id)	2,000	3	6,000
PVC Union (Male/female) (21mm)	1,600	1	1,600
PVC "T" (21 mm id)	900	3	2,700
PVC Union (21 mm id)	500	1	500
Hose pipe (21 mm id)	1,640	10	16,400
Gl pipe (21 mm id)	1,800	8	14,400
Ball tap (21 mm)	12,000	1	12,000
Gl elbow (21 mm id)	1,500	1	1,500
PVC glue	6,000	0.1	600
Car inner tubes (worn)	15,000	0.5	7,500
		VND	321,100*

*US$=29.2

Table 11. Input & output data for plastic tube biodigesters in Binh Dien and Xuan Loc villages

	Binh Dien	Xuan Loc	SE/P
Gas, litres/m^3 liquid volume	91.9	138	±25/0.238
Manure, kg/day	8.8	22.5	±2.15/0.002
Water, kg/day	76.8	65.2	±6/0.197
Water/Manure	9.3	3.08	±0.45/0.000
Gas, litres/kg DM	248	153	±32.5/0.085

Table 12. Material loaded and effluent composition

	Material Loaded	Effluent	SE/P
N, % in DM	2.85	2.49	±0.45/0.6
COD, mg/kg	29,291	7,906	±2,108/0.000
E. Coli, Colonies/g	261×10^5 ^{5} 0	1.5 x	
±38x10^5/0.000			

Table 13. Evaluation of the biodigesters in Binh Dien village

Benefits	Problems	Future Activities
-Saving time -Cleaner kitchen - Less labour spent for cooking - Good health for the "cook" - Saving money for buying and labour for collecting fire wood - Using effluent for watering duck weed, crops and trees - Preventing bad smell - Preventing flies and mosquitos	- Flood damages digesters - Animals can damage the plastic - Lack of manure in poor farms - Cattle dung products less gas than pig manure - Antibiotics used to treat pigs reduce the gas production - Cattle dung can form a hard layer on the top of the liquid in the digester - Biogas plan must be "well" conected with animal house and the kitchen	- Perfect installation proceedings - The walls of trench will be more inclined - Technical follow up! - The fence always needed - Do not let the waste into the digester when the animals are sick (applying antibiotics) - Combination between the farmers' contribution and outsiders' help - The fence always needed

Source: Binh Dien village, 1995

Table 14. Evaluation of the introduction of duck weed in Binh Dien

Benefits	Problems	Future Activities
- Pigs fed with duck weed grow very fast	- Heavy rain lets duck weed "escape", dilutes nutrients in pond - New for us: "lack of experience"	- Good drainage system - The pond must be close to the biodigester. - Continue the project

Source: Binh Dien village, 1995

Table 15. Evaluation of use of Mong Cai breeding sows

Benefits	Problems	Future activities
- Adapted and grow very well - Can use crop residues	-Difficult to find	- Training on "breeding sows" - Continue the project

Source: Binh Dien village, 1995

Table 16. Evaluation of biodigesters in Xuan Loc village

Benefits	Problems	Future activities
- Enough manure, enough gas. - Better than fire wood for cooking - Clean kitchen. - Good for small households. - Saving labour for fire wood collection.	- Rain decreases gas production. - When there is not enough gas for cooking we are less efficient!. - Feeding cattle dung can form hard layer in the top of the liquid in the biodigester - Flood can break the trench - The technology has less impact in up land region where fire wood is available	- Improve gas production - Protection (fences) - Installing for small families. - Mantenance is needed regularly.

Source: Xuan Loc village, 1995

Table 17. Evaluation of the introduction of duck weed in Xuan Loc

Benefits	Problems	Future activities
- Animals fed duck weed grow very fast. - High yield. - Easy to manage.	- Flood drives out the duck weed - less yield in rainy season.	Plant again after December

Source: Xuan Loc village, 1995

Table 18. Performance of Mong Cai sows in Binh Dien Village

Items	Average	n
1st mating weight, kg	51.7	16
Live weight gain to 1st mating, kg/day	0.223	16
No. of piglets/litter	11	49
No. of piglets weaned/litter	10	49
Mortality, %	8	48
Weight of piglet weaned, kg	8	47
Lactating days	51	47
Open days	16	46
Farrowing interval, days	181	47
Income/litter, VND	800,000.00	7

Source: Binh Dien, 1995

Table 19. Feed resouces used for breeding pigs in Binh Dien village

Family	Growing Sow	Pregnant Sow	Lactating Sow
Mr Nguyen Van Ve	Rice Rice bran Cassava meal Wine by-product Vegetables (Sweet potato an ipomea leaves)	Rice Rice bran Cassava meal Wine by-product Vegetables (Sweet potato an ipomea leaves)	Rice Rice bran Cassava meal Wine by-product Vegetables (Sweet potato an ipomea leaves)
Mr Tom	Rice, Rice Bran, Sweet potato leave, Bon e flour Cassava (no often) After the 4th Month supplement some fish flour and mineral premex	Rice, Rice Bran, Sweet potato leaves, Bone flour Cassava (no often) After the 4th Month: supplement some fish flour and mineral premex.	supplement: green beans and fish meal After 30 days the piglets are fed with rice soup and bone flour
Mr Vo Dat	Rice, Rice bran, Wine by-product, Vegetables	Rice, Rice bran, Wine by-product, Vegetables	Suplement: Green been Sticked rice, 20 days after the farrow. After they reduce and increase wine by-product
Mr Gan	Rice, Rice bran, vegetables According with the family conditions	Rice, Rice bran, Wine by-product, Vegetables	Increase the amount of rice and add sticky rice
Mrs Bui thi Chi	Wine residuo, Rice, Vegetables, Salted fish and shrimp heads	Wine residuo, Rice Vegetables, Salted fish and shrimp heads	They increase the amount and add some sticky rice
Mrs Luong Tri	Rice, Rice bran, Vegetables Small fish	Rice, Rice bran, Vegetables Small fish	For 10 days green been Sticky rice
Mrs Chung	Rice, Rice bran, Vegetables Jack fruit seed, Cassava	Rice, Rice bran, Vegetables Jack fruit seed, Cassava	Suplement. Salted fish Sticky rice with sugar
Mrs Dieu	Rice, Cassava, Vegetables Some times rice bran	Rice, Cassava, Vegetables Some times rice bran	Suplement: Green been Sticky rice
Mr s Nguyen thi Muc	Rice, Rice Bran, Vegetables	1 week before farrowing Sticky rice, green bean Duck eggs	for two weeks Green bean Duck egg
Mrs Le Thi Tam	Rice, Rice bran, Vegetables	Rice, Rice bran, Vegetables	Suplement: Sticky rice Green been, Groundnut cake

Source: Binh Dien, 1995

Table 20. Distribution of Cattle and pig population according to wealth rank in Xuan Loc village in 1990 and 1994

	Total Fam.	%	% Fam. Cattle	Popul. Cattle	% Fam. Pigs	Popul. Pigs
Better off						
1990	22	10	100	110	100	66
1994	33	9	100	760	100	209
Poor						
1990	50	22	55	85	70	140
1994	109	30	70	450	80	511
Very poor						
1990	155	68	10	30	50	100
1994	222	61	40	243	60	360

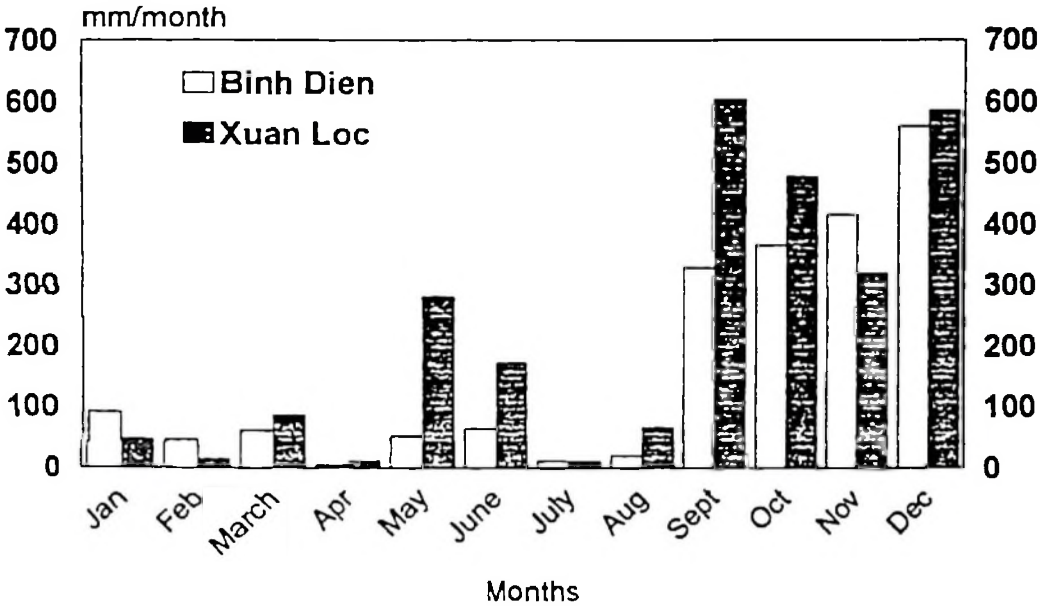
Source: Nguyen Thi Loc et al 1996

Table 21. Distribution of Cattle and pig population according to wealth rank in Binh Dien village in 1990 and 1994

	Total Fam.	%	% Fam Cattle	Popul. Cattle	% Fam. Pigs	Popul. Pigs
Better off						
1990	15	3	90	120	90	60
1994	55	10	55	300	64	120
Poor						
1990	60	11	60	84	60	120
1994	165	30	30	360	79	365
Very poor						
1990	447	86	10	0	30	100
1994	337	60	3	39	67	528

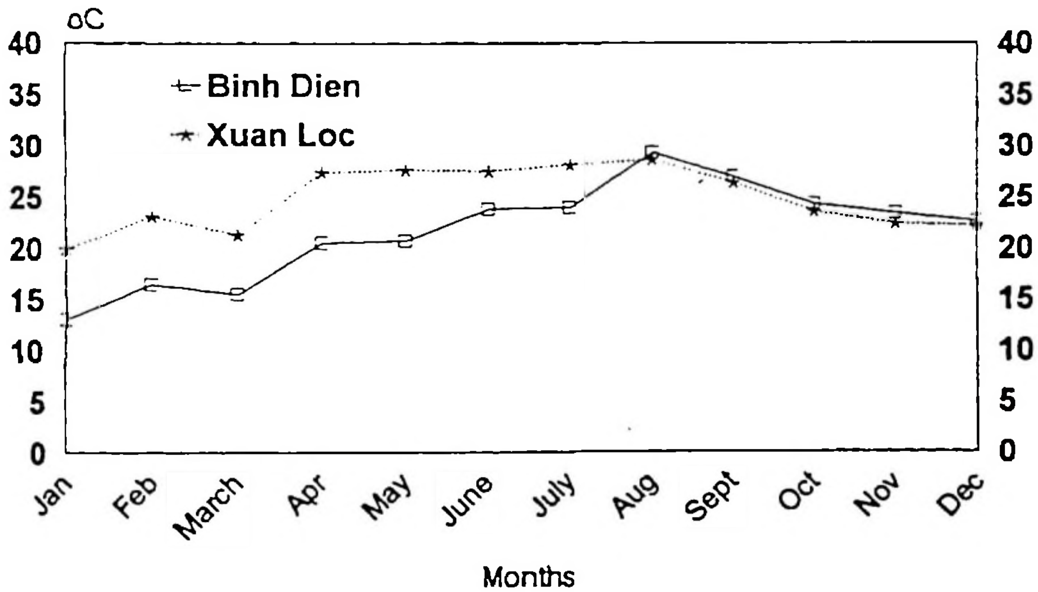
Source: Nguyen Thi Loc et al 1996

Figure 1. Rainfall distribution in Binh Dien and Xuan Loc Villages



Source:Forecast Station Service- Thua Thien Hue province, 1995

Figure 2.Mean daily temperatures in Binh Dien and Xuan Loc Villages



Source:Weather forecast Station Service- Thua Thien Hue province, 1995

Figure 3. Integrated System

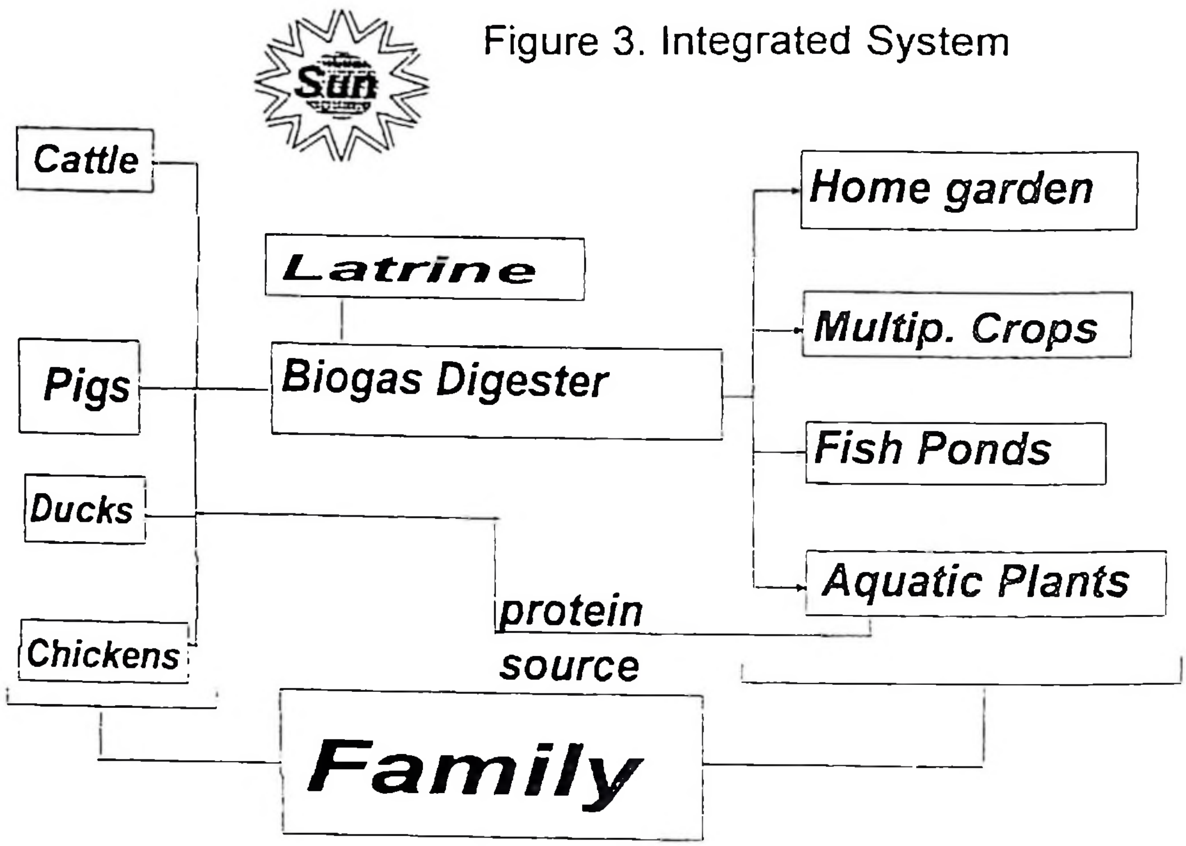


Figure 4. Duck weed production in Xuan Loc Village

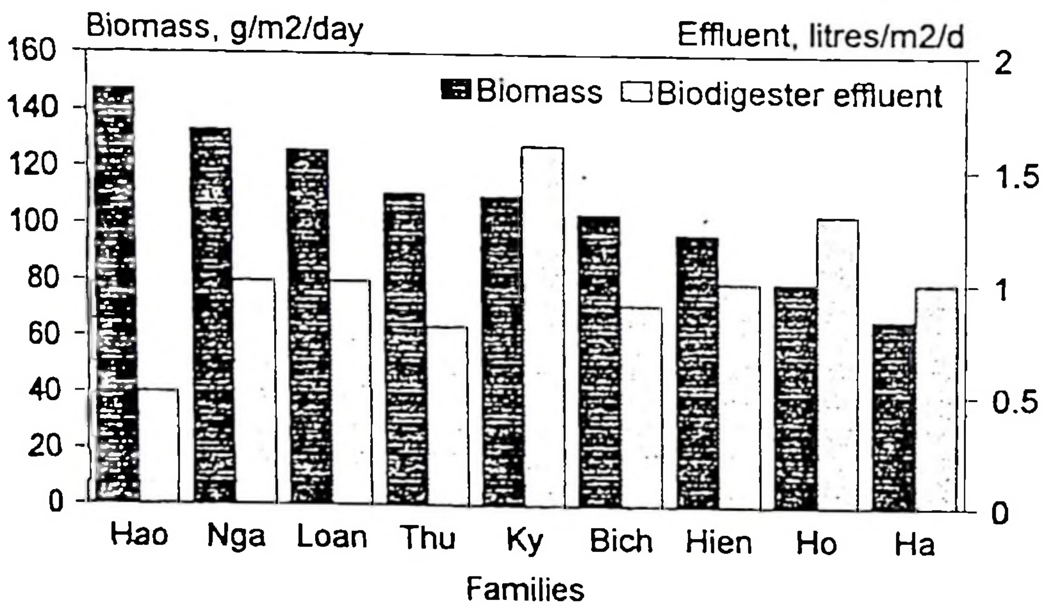


Figure 5. Low cost plastic biodigesters in Central Vietnam

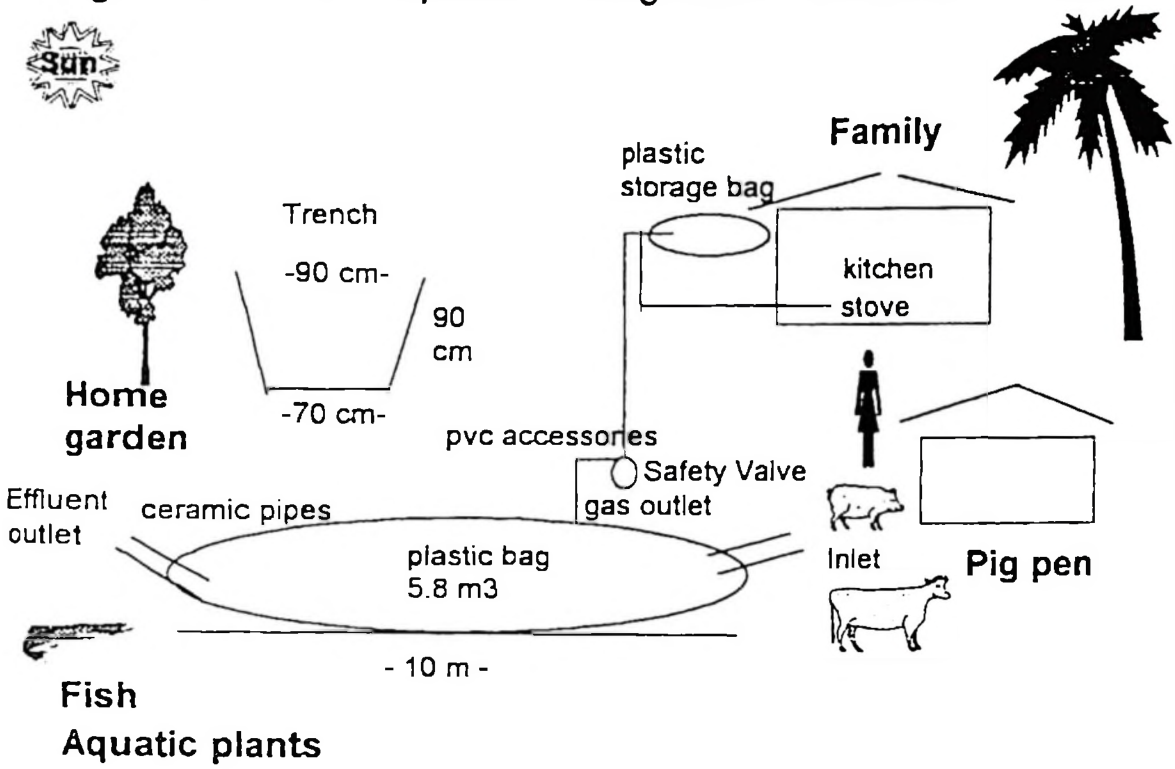


Figure 6. Relationship between excreta loading rate and biogas production in 16 biodigesters in Binh Dien and Xuan Loc villages in Vietnam

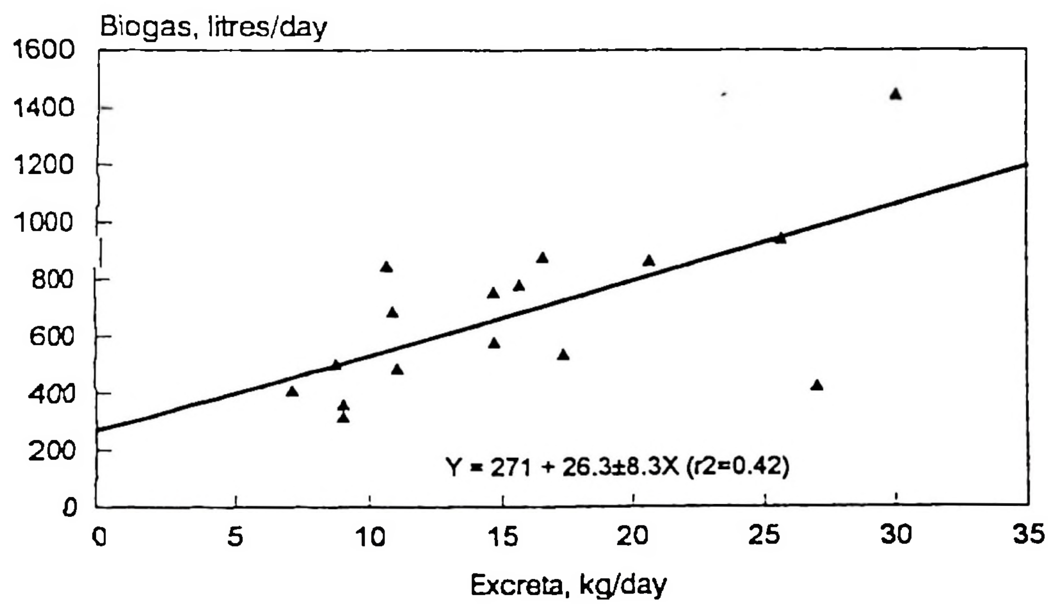


Figure 7. Litter size at birth and weaning for Mong Cai sows in Binh Dien Village

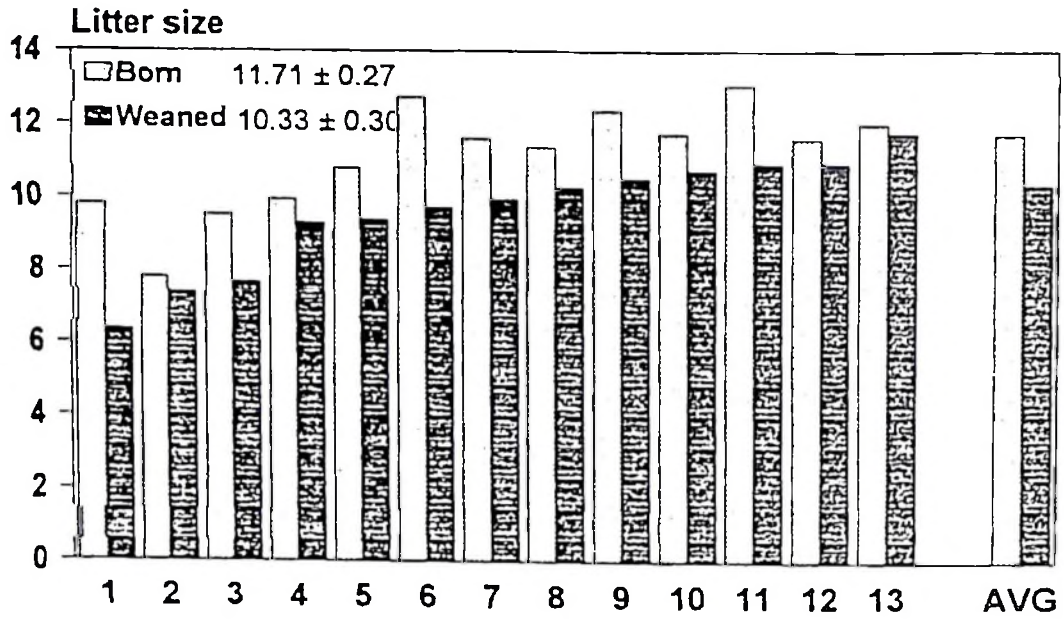


Figure 8. Longevity and prolificacy of Mong Cai sows in Binh Dien Village

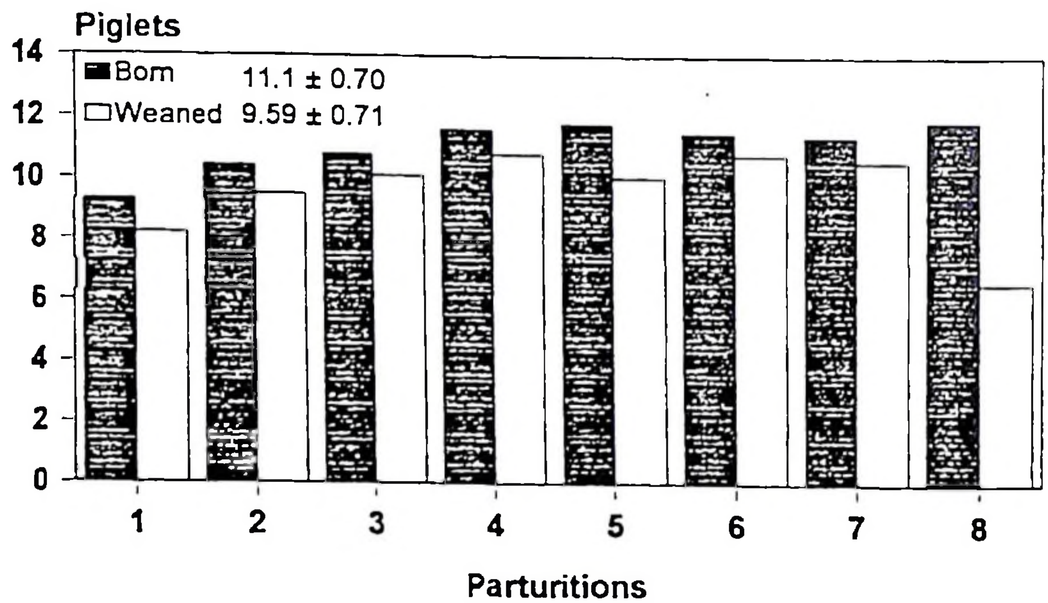


Figure 9. Farrowing Interval in Mong cai sows in Binh Dien village

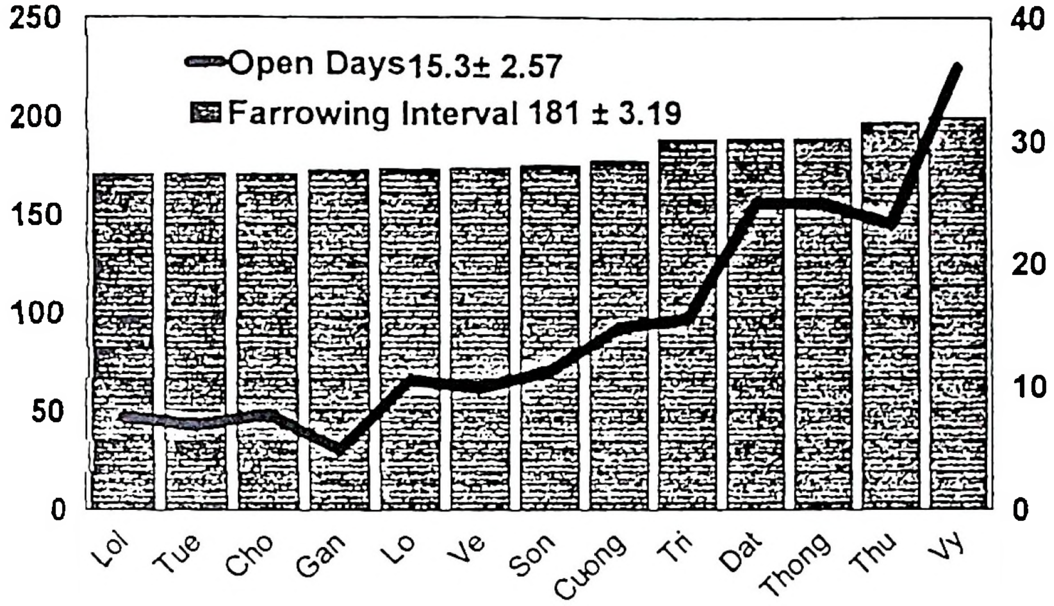


Figure 10. Weaning Weight for Mong Cai Crosses

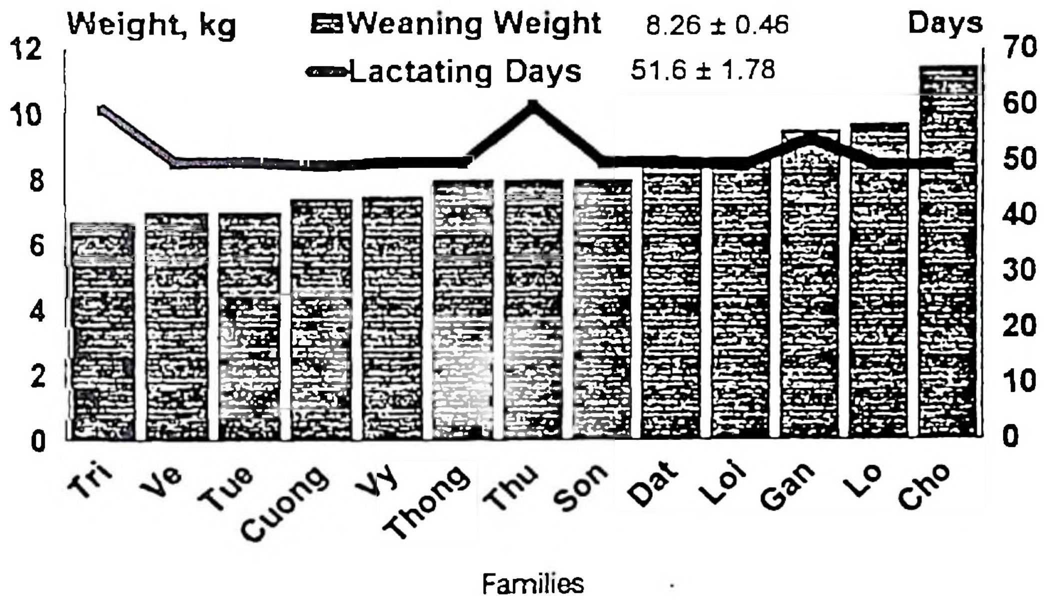
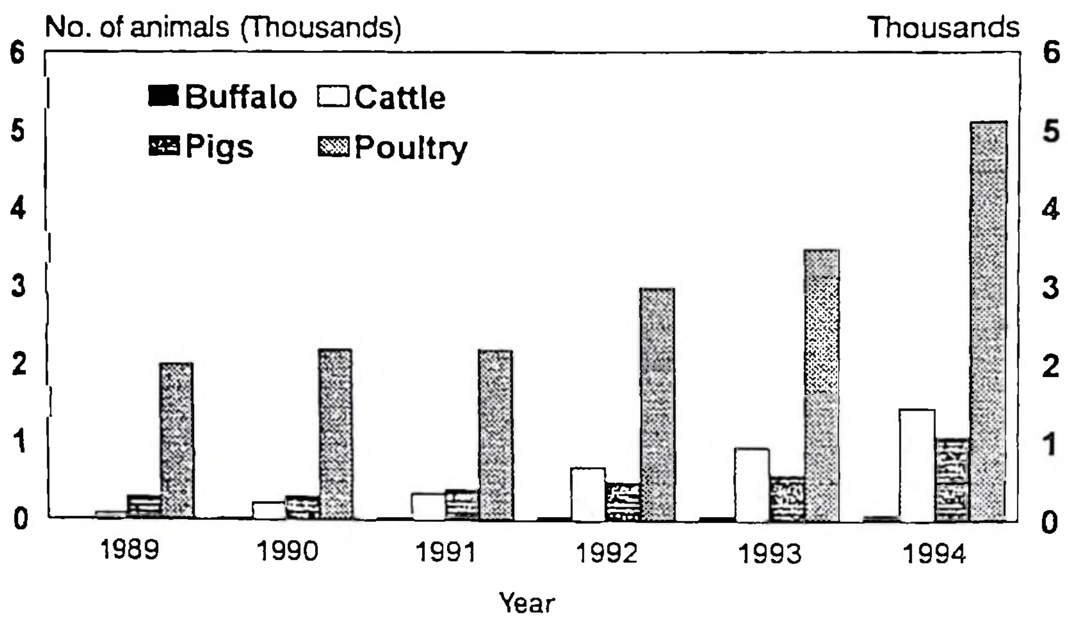
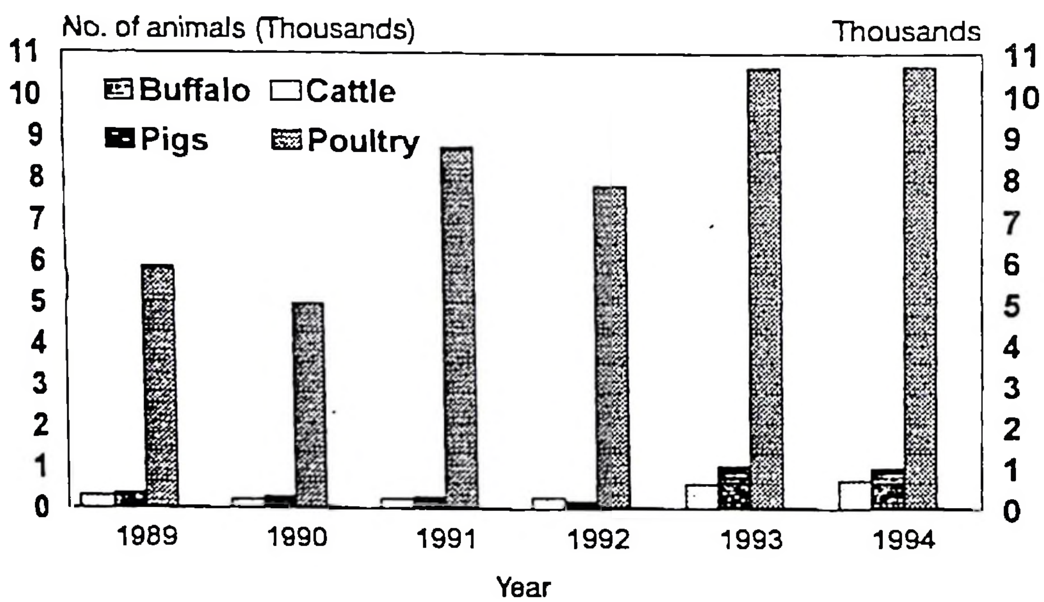


Figure 11.Changes in animal population in Xuan Loc Village



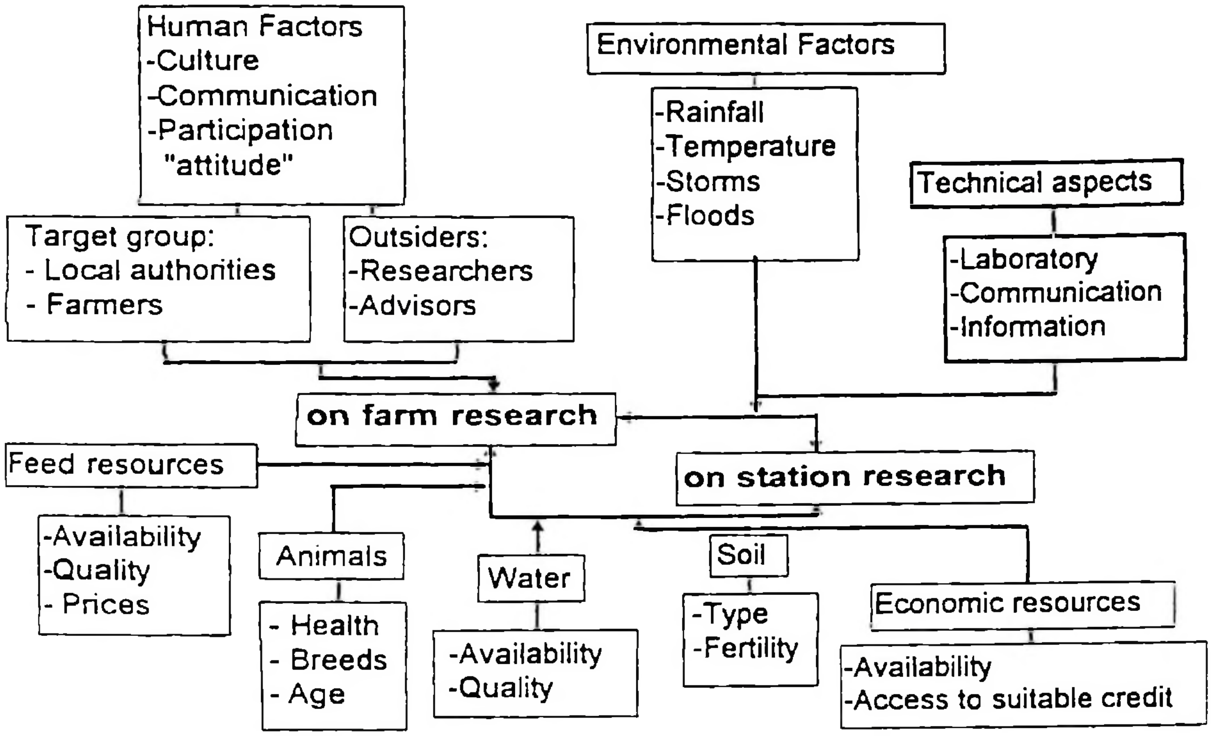
Source: Adapted from Nguyen Thi Loc et al 1996

Figure 12.Changes in animal population in Binh Dien Village



Source: Adapted from Nguyen Thi Loc et al 1996

Figure 13. Factors interacting in "on farm research" and "on station research"



Annex 1. Proposal Project made for the Women's Union in Binh Dien Village (original in Vietnamese language)

The Socialist Republic of Vietnam
Independence - Freedom - Happiness
Proposal Project

"On Developing Biogas Digesters"
Women Union Binh Dien Village

1. General Characteristics. Binh Dien commune is on the hills in the South-West of Hue. This commune was established in 1975. A large area is available which is advantageous to develop animal production and agriculture. Poor women make up high rate. They are all industrious, hard working and they all try the best to build and settle down their lives in the village.

2. Climatology: The weather is quit good, suitable to planting fruit-trees, long term and short term crops and for animal production as well.

3. Population: (in a whole commune): There are 556 households and 2957 people:

Male:	1513	Female:	1440
Male labours:	749	Female labour:	701

4. Total area: 2498 ha, consisting of natural forest, planted forest and crop production (595 has)

5. Animal Production

Cattle:	800
Pigs:	1,200
Buffalo:	49
Chicken:	3,892
Ducks:	450

II. Background

1. In 1995, being helped by the SIDA-SAREC MSC course, our Women Union could make 28 Biogas Digesters to use the pig and cattle manure in order to produce gas methane for the family and we realize that it has many good points.

2. Results:
- Reducing labour time of cutting fire wood in remote forest.
- Reducing exploitation of the forest.
- Using gas makes the environment pure.
- Using gas for cooking we can keep clean the pans.
- Using effluent from the biodigester to fertilize fields, fruit trees such as bananas, lemon, chili, vegetables, etc.
- The most important thing is to reduce the amount of money for families that have to buy wood to cook because of lacking of labour to cut fire wood in the forest.

In reality, using gas for cooking is possible to reduce in a 100% the fire wood for a four-member family and 60% for a family six or more members.

After seeing the 28 Biogas Digesters in Binh Dien, many women want to have their own one. They realized that it is very advantageous for women. Now the standard of living in our commune still low, therefore they cannot afford to pay for it.

On behalf of Binh Dien Women I would like to request a financial support at the beginning in order to preserve and to develop the Biogas Digesters, which will be expanded in other surrounding areas in the future.

Binh Dien is one of the 15 communes of Hung Tra District and is the first to invest and build Biogas Digesters in TT Hue province. This is the newest and the most interesting thing to farmers in this countryside. Until now, there are a large number of visitors who want to use gas-cookers after having seen gas-cookers by themselves. They live at Huong Binh, Huong Van, Hue, 10-43 km far from Binh Dien.
Through the reality mentioned above, our Women Union would like to be the first unit applying the new scientific technological methods to continue developing in making Biogas Digesters for farmers living in 15 communes of Hung Tra District.

III. How to carry out the plan

- We plan to have a group of 4 officers (1*) They all will be trained in Biogas Digesters. One of them will have the responsibility to control the work.
- The group will introduce the advantages of use the Biogas Digesters to 15 communes of Hung Tra District and perhaps cover a wider area.
- We will install the biodigesters and we will ask the materials cost plus $100,000 VND per biogas for the labour (2*) and the follow up maintenance, this money will be used as revenue to support the project in the future.
- We include training for two people in Ho Chi Minh city (Bui Xuan An) before starting the project (a local Binh Dien person and a University support person) and local workshops to train people and exchange experiences (3*).
- Advertisement (Videos, leaflets and training material) (4*)
- University Support: to work in connection with a network of biogas digester researchers (centre in Ho Chi Minh City), to continue the research in adapting the technology to conditions in T.T.-Hue Province and diverse household situations, and to serve as facilitator in technology transfer, we will provide an honorarium and travel expenses (5*) to one lecturer in rural development at Hue University of Agriculture and Forestry.
- At the end of the project year, we will invite a researcher from Ho Chi Minh City (Bui Xuan An) to evaluate and assess the project thus far and make recommendations for future work.

To carry out the project we would like to request a financial support.

IV. Budget (1 year)

Officers (1*) salary @$300,000.00 VND/mo.	14,400,000
Material and labour for 50 biodigesters (2*) $ 450,000.00 VND	22,500,000
Motorcycle for the officers	17,500,000
Travelling expenses for the officers	1,500,000
Training (3*)	9,000,000

- 2 people to HCM City @ 1,5 million each
- 6 local workshops @ 1 million each

Advertisement and Training (4*)	1,000,000
University support (5*)	6,200,000

- 52 days @ 100 000/day + travel expenses @ 20 000/day

End of year assessment and recommendations
2,000,000

- Travel from HCM City
- Honorarium for 7 days @ 100 000 VND/day

Total $ VND 74,100,000

There will be 2 methods of credit/installation programme:
1. Those wealthier households will pay for the materials and labour immediately or upon first signs of gas production.
2. Those poorer households will enter a credit system. Farmers will repay by monthly installments in up to 10-12 months.
These two systems will ensure access to biogas technology to some poorer families while ensuring some revenue to self-sustain the project.

This is the intention and desire of Binh Dien Women Union in the future. We hope we can get the financial support to carrier out this project which will be very important to improve our standard of living.

PHAN THI DUONG CHI
Binh Dien, September 19, 1995
On Behalf of Binh Dien Women Union

Women Workshop in Binh Dien and Xuan Loc villages - Hue Province
Workshop report presented to FAO

Binh Dien Village Monday, December 4Th 1995
Participants: Laders of the Women Union Binh Dien Village, people's committee and 55 women farmers

1. Introduction of the participants and objectives

2. Some Experiences in Colombia with *trichantera gigantea*
   Lylian Rodriguez

3. *Trichantera gigantea* in the South of Vietnam
   Mrs Hong Nhan

4. Biogas Production: "Practical Suggestions"
   Bui Xuan An

5. Multi nutritional Blocks
   Bui Xuan An

6. The use of the cassava leave ensilage to feed pigs a new alternative
   Nguyen Thi Loc

7. Practical work and distribution of *trichantera* steams and *Griricidia sepium* seeds
   - Planting *Trichantera gigantea*
   -Making Multi nutritional blocks with molasses and without molasses

8. Lunch together

Xuan Loc Village Tuesday, December 5Th 1995

Participants: Leader of the Women Union Xuan Loc Village and some leaders from the people's committee and 14 women farmers and 3 men farmers

1. Introduction of the participants and objective.

2. Biogas Production: "Practical Suggestions"
   Bui Xuan An

3. Some experiences with Trichantera gigantea in the South of Vietnam
   Mrs Hong Nhan

4. The use of the cassava leave ensilage to feed pigs a new alternative
   Nguyen Thi Loc
5. Practical work and distribution of *Trichantera* steams and *Griricidia sepium* seeds
   - Planting *Trichantera gigantea*

6. Lunch together

COMMENTS

The workshop was very useful and could be the point to start to develop a protein source in the village which is very important for farmers and research could be done as well. People were very interested specially in Binh Dien Village and farmer were selected in each village for the women union in order to develop the tree in the village and in the future other farmers can get the material to plant from them.

The suggestions in Biogas digesters were relevant because there is a project (more than 50 biogas digesters) already going on so farmers were interested in this subject.

Cassava is one of the main crops in both villages so, the use of cassave leaves ensilage is another alternative of protein from local resources.

Multi nutritional blocks were introduced in the village for the first time and people showed up interest in the new technology specially because of the hard conditions for the cattle during certain parts of the year. More work most be done in this aspect.

Slides, posters with big pictures, printed material and practical work were used as a way to show the different experiences.

In general it is an easy way to exchange ideas and experiences with farmers and it is very important to say that the facilitators were very clear in their presentations which made the workshop successful.

Lylian Rodriguez J
SAREC MSc Student

II

USE OF EFFLUENT FROM LOWCOST PLASTIC BIODIGESTERS AS FERTILIZER FOR DUCK WEED PONDS

Lylian Rodríguez J[1] and T R Preston[2]

ABSTRACT

The hypotheses that were evaluated in this study were that: effluent from biodigesters would be an effective source of nutrients with which to grow duck weed of high protein content; and the protein level in the duck weed would be a function of the amount of effluent added to the pond water.

Six ponds were used, each lined with polyethylene film (0.2mm thickness) having 9.4 m^2 area and 15 cm water depth. The two treatments were 32 and 4.5 kg effluent/m^3 pond water ,which were estimated to support N concentrations in pond water of 73 and 10.3mg N/litre respectively. The effluent was from plastic tube continuous flow biodigesters, charged with pig manure, and contained 6.5% of solids and 3.41% of N in the solids. 200 g of duck weed/m^2 were added to each pond and the total biomass was harvested at 3 day intervals over a period of 9 days. The yield of duck weed was calculated by substracting the amount of seed material that was planted.

Biomass yield and protein (N*6.25) in the duck weed dry matter were linearly related with the N concentration in the pond water and negatively related with root length of the duck weed. Optimum levels of N in pond water were in the range 40-60mg N/litre. Duck weed of more than 35% protein had a root length less than 10mm. Duck weed biomass yield at optimum pond N levels was of the order of 100 g fresh biomass/m^2/day with 6% dry matter and 30-40% protein (N*6.25) in the dry matter.

Based on these results, and other observations, the recommended management practices to optimise duck weed yield and protein content are: (i) an initial charge of 33 kg of effluent containing 6.5% solids and 3.4% N in the solids (or comparable amounts to provide 75g N)/m^3 of pond) and; (ii) 1.0kg effluent/day/m^3 for 27 days, after which the ponds should be emptied and recharged with effluent and "good quality" (root length of less than 10mm) duck weed.

Key words: Biodigester; Effluent; Duck weed; Lemna; Integration; Ponds; Nitrogen; Protein

INTRODUCTION

Where rainfall is adequate or there is supplementary irrigation, water plants can be highly productive sources of protein-rich biomass and are ideal complements for fibre-free basal diets

1

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such as molasses, sugar cane juice, sugar palm juice and palm oil in pig and poultry feeding systems. The leaves of most water plants are more digestible than the leaves from trees and, generally, they appear to have low concentrations of anti-nutritional factors (Preston 1995).

The water fern *Azolla spp* is one of the aquatic plants that has had good impact with farmers because of its high growth rate, relatively simple management and easy incorporation in feeding systems for pigs and ducks (Becerra 1991). Observations in Colombia (Rodriguez Lylian and Cuellar Piedad 1994) showed that Azolla can produce an average of 60 g fresh biomass/day all year round, although there was a tendency for it to grow better during the rainy season. It supplied 100% of the protein requirements of lactating sows in diets based on sugar cane juice without any decrease in their performance.

Another potential resource is duck weed (family *lemnaceae*). Lemna or duck weed as it is commonly known, is a tiny green plant that grows on pond surfaces. It is easily identified by the presence of only one root per small green frond. This plant grows well in different climates, and is a fast growing, high protein plant that can efficiently absorb nitrogen and phosphorus as well as heavy metals (Logsdon, 1989 cited by Becerra et al 1995).

A World Bank project in Bangladesh showed that fish yields of an average of 10 tonnes/year/ha were obtained using only duck weed as a supplement to the naturally available fish feed (Skillicorn et al 1993).

Becerra et al (1995) concluded that fresh duck weed as source of protein can only be used in limited amounts to substitute for conventional protein in the diets of fattening ducks. There were no adverse affects on health, but decreases in growth rate and in feed conversion efficiency were considerable when duck weed replaced more than 20% of the soya bean protein. In contrast, Bui Xuan Men et al (1995) showed that fresh duck weed could completely replace roasted soya beans and a vitamin-mineral premix in broken rice based diets for fattening ducks without reduction in grow performance or carcass traits. A major difference between the two experiments was that Becerra et al (1995) worked with duck weed of only 26% crude protein, whereas Bui Xuan Men et al (1995) used duck weed growing in water which had been fertilized with biodigester effluent and contained 38% crude protein in the dry matter.

The fact that protein yields of duck weed can be as high as 10 tonnes/ha/year (Preston 1995) compared with less than one tonne per year for soya bean protein highlights the potential value of this plant at the farm level. The critical factor appears to be the protein content, which in turn depends on the nutrient status of the medium on which it is grown. This relationship was shown by Stambolie and Leng (1995) when they analysed duck weed (*Spirodela spp*) grown on sewage water. The protein content rose from 20% to almost 40% in dry matter as the N content of the water was increased from 5 to 40 mg/litre.

The hypotheses to be evaluated in this study were:

- Effluent from biogas digesters would be an effective source of nutrients with which to grow duck weed of high protein content.
- The protein level in the duck weed would be a function of the amount of effluent added to the pond water.

MATERIALS AND METHODS

Location

The experiment was carried out at the "Finca Ecologica" on the University Campus (UAF-University of Agriculture and Forestry in Ho Chi Minh Vietnam), a small farm established by one of the authors (TRP) to demonstrate integrated farming systems with perennial crops, multi-purpose trees, local breeds of livestock, low-cost plastic biodigesters and duck weed ponds. The area is close to sea level with ranges in temperature from 24 to 38°C, and relative humidity in the range 40 to 100%.

Ponds and biodigester

Plastic lined ponds were used because of the sandy soil and the need for uniformity among the ponds. They were built using the same sort of polyethylene plastic used for the biogas digesters (0.2mm thickness). There were 6 ponds of 9.4 m^2 area and 15 cm water depth. The ponds were located close to the biogas digester to facilitate the use of the effluent. Soil was excavated to about 15cm and the plastic sheet supported with bamboo poles to gave a total pond depth of 25cm.

The mixed effluent from 4 experimental biodigesters was used. Each measured 4m long and 0.84m in diameter with 1.5 cubic metres liquid volume. They were charged with pig manure and water to give a solids concentration of 2, 4, 6 and 8% for individual digesters. The loading rate was 50 kg/day of the mixtures.

Design and treatments

Six ponds were used. The two treatments (each replicated in 3 ponds) were 32 and 4.5 kg effluent/m^3 pond water. 200 g of duck weed/m^2 were added to each pond and the total biomass was harvested at 3 day intervals. The yield of duck weed was calculated by subtracting the amount of seed material that was planted. After each harvest the same amount of seed was put back again. Samples of water and duck weed were collected at each harvest for determination of nitrogen and dry matter and for measurements of root length.

Management and data collection

The yields of duck weed were determined by weighing the total amount of biomass from each pond. Bamboo sticks, the width of the ponds, were used to harvest the duck weed. To measure the length of the roots, samples of duck weed were suspended in plastic containers of 8cm diameter filled with water. Root length was measured by extending 10 individual plants from each sample on millimetric paper and taking the average length.

Dry matter was determined by weighing before and after drying for 48 hr in an oven at 100°C and nitrogen by Kjeldahl (AOAC 1988) using a Tekator Kjeltec apparatus. The samples of duck weed were analysed immediately after harvest because when the samples were stored in a refrigerator there were obvious physical changes in their appearance and it was considered this might affect the results.

Samples of water for N determination were taken immediately after harvesting the duck weed. The pond contents were agitated and samples were taken from different points in each pond. These were mixed and the N determination done on the fresh samples using the Kjeltec apparatus.

RESULTS AND DISCUSSION

The effluent added to the ponds contained 6.5±0.65% dry matter (mean and SE) and 3.41±0.13% N in the dry matter. Relationships between the amounts of effluent added to the ponds, the N content of the pond water, the biomass yield, theN*6.25 content of the duck weed and the root length are shown in Figures 1 to 6. The basic data are in Annex 1.

At the first harvest, fresh duck weed yield was in the range 55 to 65 g/m²/day and did not differ between effluent levels (Figure 1). By the second harvest the yield on the low level of effluent had fallen to 31 g/m²/day while in the ponds with the high effluent level yield had increased to 110 g/m²/day. At the third harvest yield on the low effluent level decreased further to 15 g while at the high level it was maintained at 110g/m²/day. The interaction between effluent level and harvest number was significant ($P=0.01$). Trends in N concentrations in the pond water (Figure 2) were similar to those for biomass yield ($P=0.13$ for the interaction of N concentration with harvest number) except that at the low level of effluent the N concentrations remained low and were not affected by number of harvests (12.8 to 15.9mgN/litre), while at the high effluent level N concentration peaked at the second harvest (53mgN/litre) and fell subsequently to the value at the first harvest (31-38mgN/litre).

Biomass yield (Y1) and protein (N*6.25) in the duck weed dry matter (Y2) were linearly related with the N concentration in the pond water (X).

$Y1 = 26.0 + 1.41 \pm 0.51X$; $r^2 = 0.32$ (Figure 3)
$Y2 = 13.3 + 0.55 \pm 0.13X$; $r^2 = 0.54$ (Figure 4)

Biomass yield (Y3), protein content of the duck weed dry matter (Y4) and N content in pond water (Y5) were negatively related with root length (Z) of the duck weed.

$Y3 = 133 - 3.71 \pm 0.94Z$; $r^2 = 0.49$ (Figure 5)
$Y4 = 56.3 - 1.49 \pm 0.15Z$; $r^2 = 0.86$ (Figure 6)
$Y5 = 56.1 - 1.55 \pm 0.36Z$; $r^2 = 0.53$ (Figure 7)

CONCLUSIONS

There was considerable variability in the data , but the overall relationships supported the original hypothesis that the protein (N*6.25) content of duck weed can be manipulated by the addition of biodigester effluent.

On the basis of the analysis of the effluent and an average fresh biomass yield of duck weed of 100g/m²/day it can be estimated that adding 45 kg fresh effluent (contains 105 g N) to 1.41m³ (9.5m² area) of pond water will raise the N content of the pond water to 50mg/litre, which agrees well fairly with the observed values (Figure 2). An average harvest of 93 g/m²/day of fresh duck weed amounts to an output from the pond of 0.31g N/day or 2.8 g N in 9 days. Thus after 3 harvests the pond should be recharged with 12 kg of effluent (containing 6.5% solids and 3.41% N in the solids) in order to maintain a constant concentration of 50 mgN/litre. In practice the following management has been applied to the ponds:
(i) An initial charge of 45 kg of effluent
(ii) After 3 harvests (9 days) an additional 24 kg effluent is applied

(iii) After 6 harvests (18 days) an additional 24 kg effluent
(iv) After 9 harvests (27 days) the ponds are emptied, a new charge of 32 kg effluent is introduced and the duck weed seed is replaced using material from another pond which appears to be of "good quality" (defined as having a root length less than 10mm; see Figure 6).

Theoretically, these amounts of effluent are higher than the absolute requirements. This implies either that not all the N in the effluent is available to the duck weed or there are losses (eg: of un-ionised NH_3) from the pond surface. This is an area requiring further research.

ACKNOWLEDGEMENTS

Appreciation is expressed to the Swedish Agency for Research Cooperation with Developing Countries (SAREC) for financing most of this study. The University of Agriculture and Forestry of Ho Chi Minh City made available the site for the Finca Ecologica on the University campus. Special thanks to Nguyen van Lai for advice on analytical procedures and assistance in the laboratory, to Vo Than Hai for help with the day to day management of the ponds and to Bui Xuan An for advice on practical problems of biodigester and pond construction and maintenance.

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Figure 1. Production of duck weed biomass with biodigester effluent (harvests made at 3-day intervals)

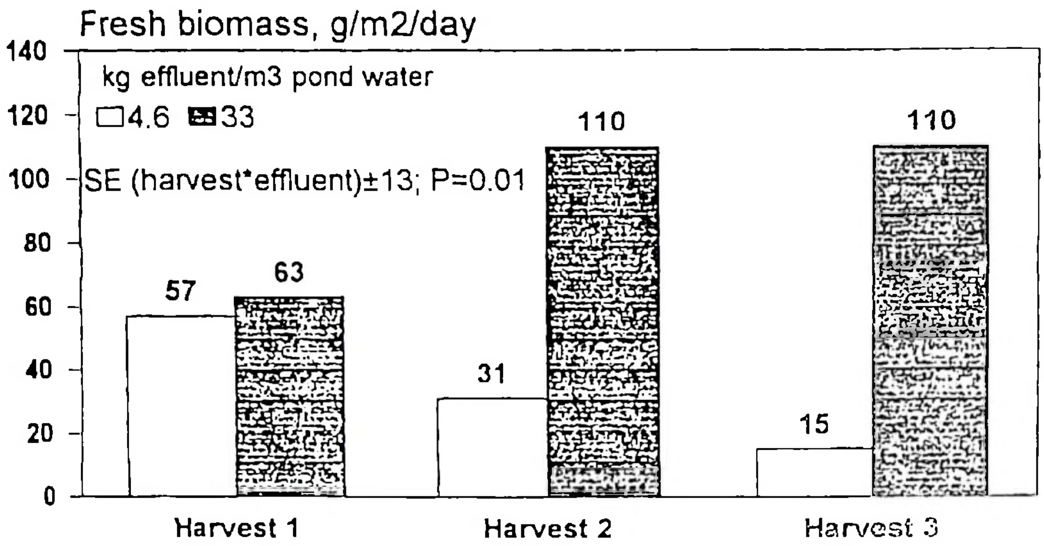


Figure 2.Production of duck weed biomass with biodigester effluent (harvests made at 3-day intervals)

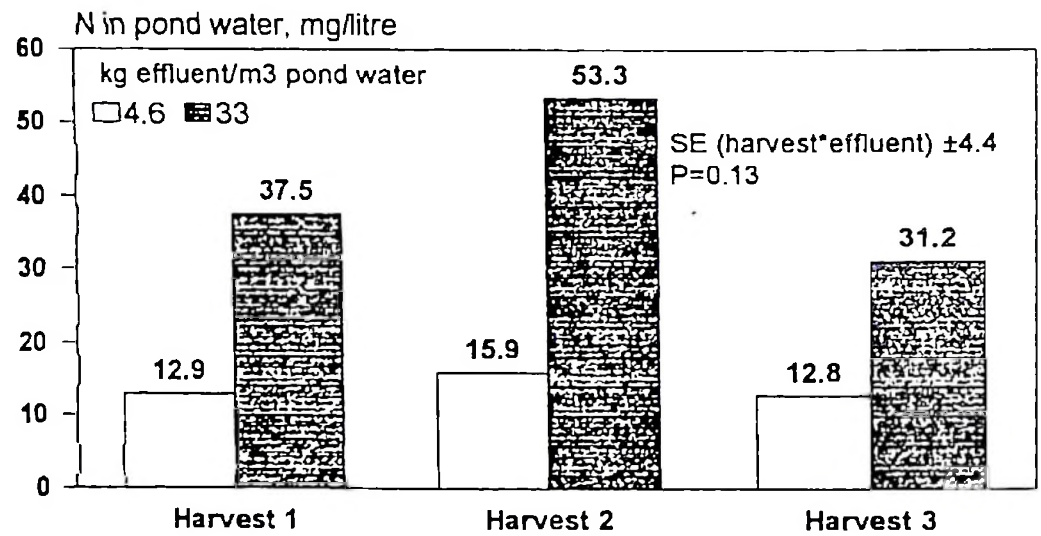


Figure 3. Relationship between N content of pond water and fresh biomass yield of duck weed

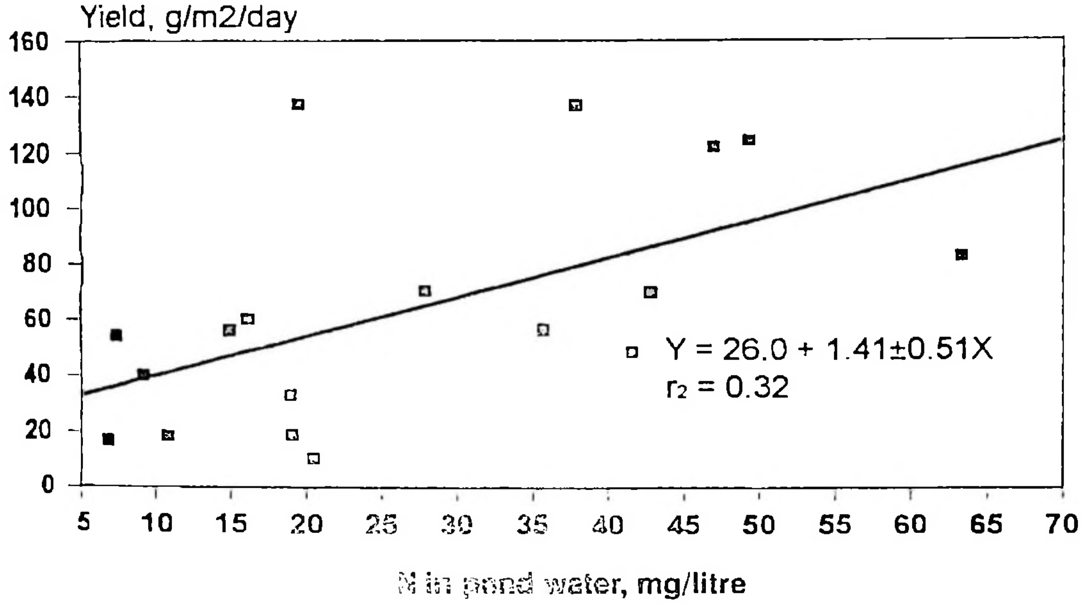


Figure 4. Effect of N content of pond water on the N*6.25 content of duck weed

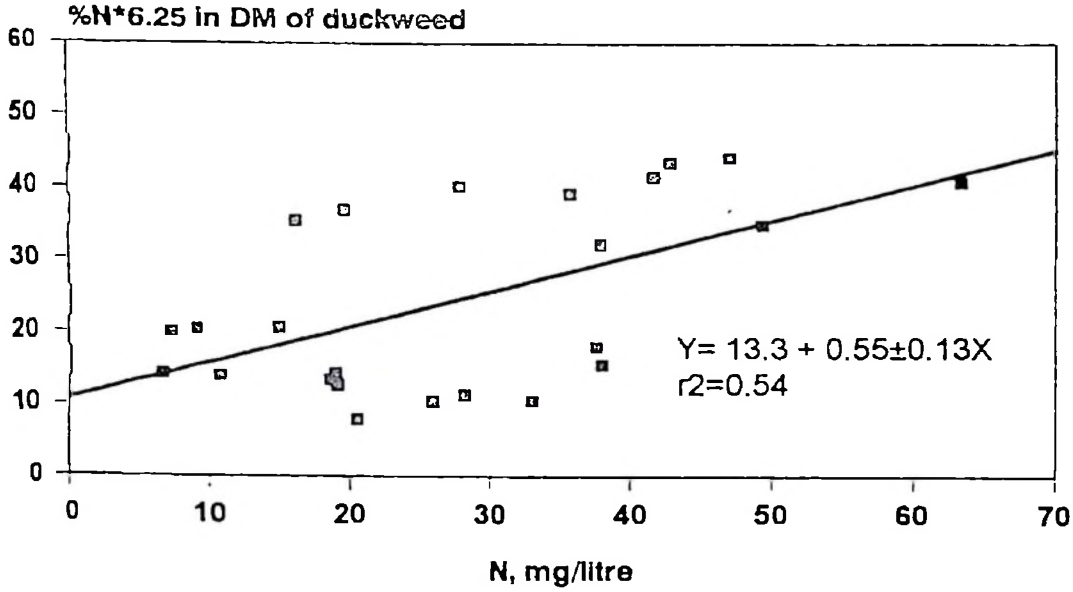


Figure 5. Relationship between root length and fresh biomass yield of duck weed

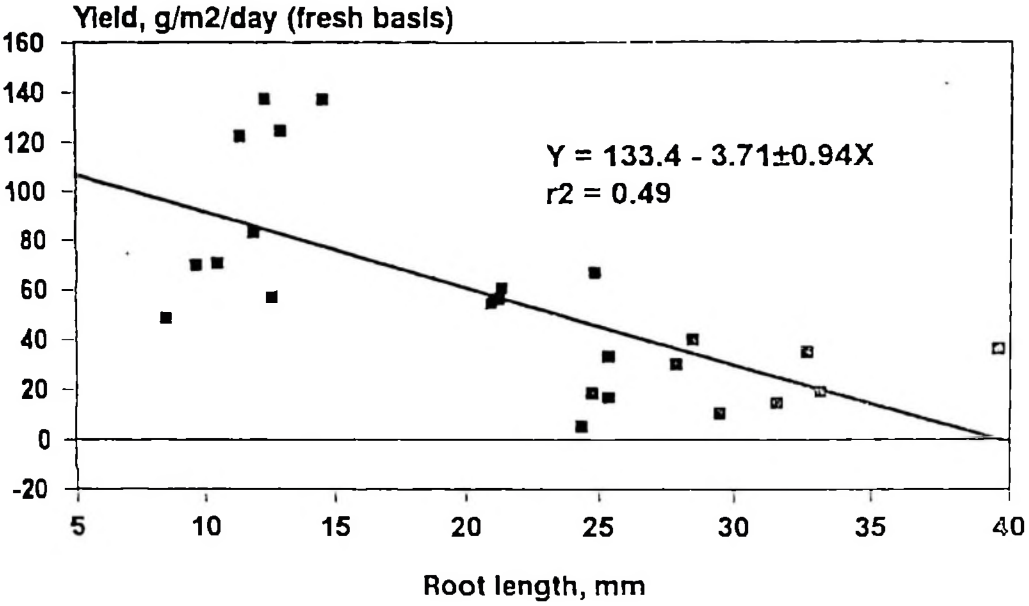


Figure 6. Relationship between root length and protein content of duck weed

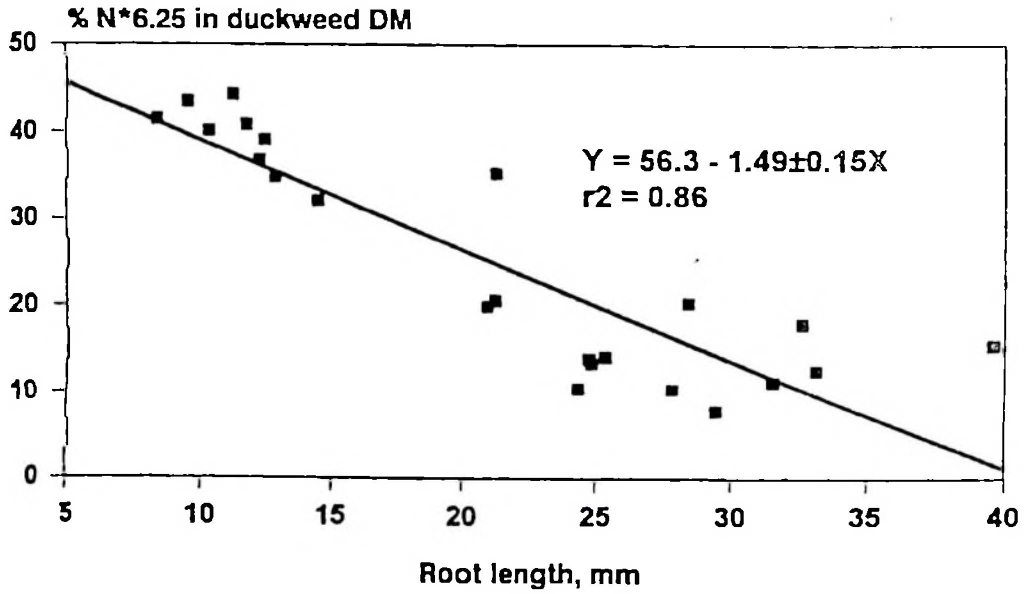
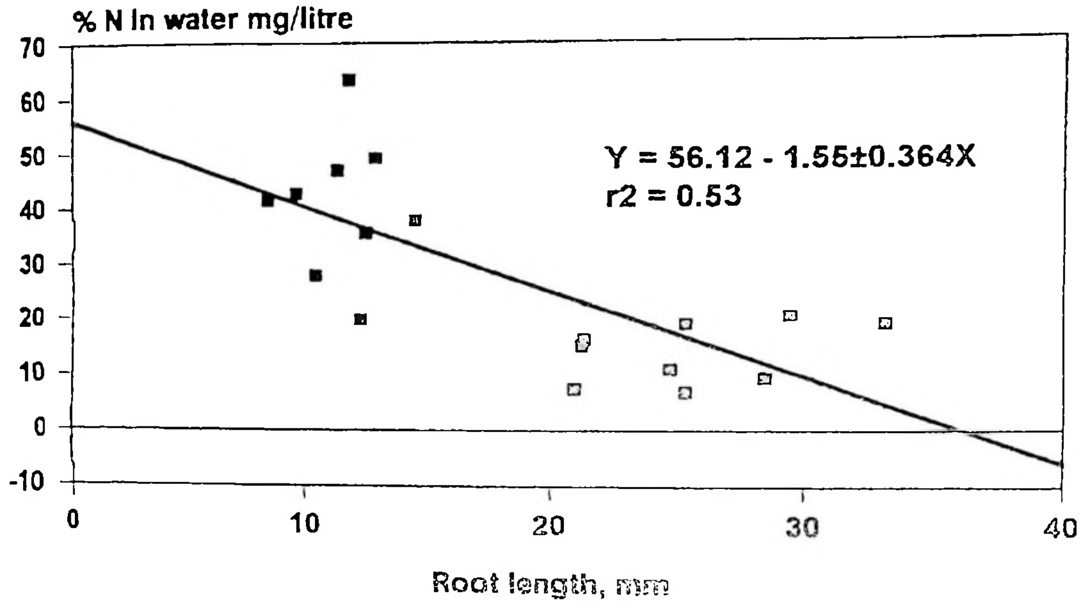


Figure 7. Relationship between root length and N in pond water



Annex 1. Experimental parameters

Level N	Harvest	g/m²/day	Roots	mg N/l wat	Lemna %DM	Lemna %N in DM	Lemna % CP
1	1	48.6	8.5	41.7	6.0	6.6	41.6
2	1	1	21.4	16.3	3.6	5.7	35.4
1	1	69.8	9.7	42.9	5.6	7.0	43.5
2	1	54.3	21	7.4	6.8	3.2	20
1	1	70.6	10.5	28	5.8	6.4	40.2
2	1	56.3	21.3	15.1	6.9	3.3	20.7
1	2	82.9	11.9	63.4	5.5	6.5	40.9
2	2	19	33.2	19.2	7.4	2.0	12.7
1	2	124.4	13	49.4	6.4	5.6	34.8
2	2	40	28.5	9.3	6.1	3.3	20.4
1	2	122.4	11.4	47.1	6.9	7.1	44.3
2	2	33.2	25.4	19.1	6.1	23	14.3
1	3	56.7	12.6	35.8	6.2	6.3	39.2
2	3	18.5	24.8	10.9	7.8	2.2	14
1	3	137	14.6	38	5.9	5.1	32.2
2	3	16.7	25.4	6.8	8.1	2.3	14.2
1	3	137.3	12.4	19.8	6.1	5.9	36.9
2	3	10.4	29.5	20.6	8.7	1.3	8.0

III

COMPARATIVE PARAMETERS OF DIGESTION AND N METABOLISM IN MONG CAI AND MONG CAI*LARGE WHITE CROSS PIGLETS HAVING FREE ACCESS TO SUGAR CANE JUICE AND DUCK WEED (*Lemna minor*)

Lylian Rodríguez J[1] and T R Preston[2]

ABSTRACT

The hypotheses to be evaluated in this study were: (i) Mong Cai pigs would eat greater amounts of duck weed (*Lemna minor*) and use it more efficiently than exotic pigs such as those of the Large White breed; and (ii) duck weed grown in ponds fertilized with biodigester effluent would be a satisfactory source of supplementary protein in a low protein basal diet of sugar cane juice. Four Mong Cai male piglets (5-10 kg) were obtained from the local market, four Large White male piglets (12-17 kg) from a nearby State farm and four Mong Cai*Large White piglets (2 male and 2 female) (9-14 kg) from a litter (Mong Cai mother; LW sire) born at the farm. They were housed in metabolism cages made from bamboo and wood (floor area 70*70 cm) with freedom to move around. The fresh sugar cane juice (19-21°Brix) and fresh duckweed (31-35% N*6.25 in DM), from ponds fertilized with biodigester effluent, were offered in separate containers in discrete meals at frequent intervals (cane juice at 12.00, 15.00, 18.00, 20.00 and 22.00 hr; duck weed at the same times with an additional meal at 07.00 hr). The juice was removed between meals and during the night, while the duck weed was available continuously.

The reaction of the exotic purebred pigs to the feeding regime was quite different from that of the Mong Cai and crosses. They would only consume (reluctantly) the duck weed when it was mixed with the cane juice; they were notoriously more aggressive, attempting to climb out of the cage and becoming extremely vociferous when the time of feeding was near. Eventually they were eliminated from the experiment.

Relationships between the percentage of diet dry matter consumed as duck weed (X) and apparent digestibility (DM and N) and N metabolism (retention as % of intake and digested N) were derived for the combined data for the 2 breed groups (8 pigs) and expressed as linear equations, the regression coefficients of which were all significantly different from zero.

The data infer that with no duck weed in the diet the DM digestibility would be 97% which is in agreement with the fact that sugar cane juice is comprised almost entirely of soluble and digestible sugars. With 40% duck weed (a dietary protein level of 13% in DM) the prediction is a DM digestibility of 83%. Apparent N digestibility of the mixtures of juice and duck weed was in the range 63 to 73%. The N balance (g/day) increased linearly with increasing duck weed in the diet. With 40% of duck weed in the diet DM, the N retained as percent of N intake was

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41% and of digested N (57%). There were no significant differences between Mong Cai and Mong Cai*Large White crosses for any of the parameters.

The results indicated that the nutritive value of duck weed is high when fed to indigenous pigs and their crosses as a supplement in a basal diet of sugar cane juice. Fifty percent of the pigs were able to consume fresh duck weed in proportions sufficient to provide a diet with more than 10% of protein in the dry matter. Purebred exotic pigs (Large White) appeared to be less adapted to consume the duck weed.

Key words: Duck weed; Lemna minor; Pigs; Sugar cane juice; Digestibility; N balance; Indigenous breeds; Biodiversity; Animal welfare.

INTRODUCTION

Duck weed has mostly been used as a feed for fish (Skillicorn et al 1993; Hassan and Edwards 1992) and ducks (Becerra et al 1995; Men et al 1995). The only report on its use for pigs is that of Haustein et al (1992)(cited by Leng et al 1995). These latter workers dehydrated the duck weed and fed it at levels of up to 10% of a complete mixed diet given to fattening pigs. Growth rates and feed conversion deteriorated with increasing level of duck weed in the diet.

The strategy of "matching systems with available resources" (Preston and Leng 1987; Preston and Murgueitio 1994) implies that these resources are used close to the sites of production and processing is the minimum required to achieve a satisfactory utilization. Freshly harvested duck weed contains more than 90% of water which makes drying difficult and almost certainly uneconomic. It was also observed that pigs preferred to consume the duck weed when it was fresh and that intake fell when partially wilted material was offered.

In the typical management system (Rodriguez et al 1996) of local indigenous breeds , such as the Mong Cai, the sows are often fed mainly with "green plants" or are allowed to roam freely, scavenging for a wide range of feeds of plant (vegetable wastes, grasses, weeds and water plants) and animal (earth worms) origin. Thus it could be expected that these animals might eat more readily (would be already adapted to) a resource such as duck weed that grows spontaneously on contaminated water surfaces as are found in many households in Vietnam.

The hypotheses to be evaluated in this study were:

- Mong Cai pigs would eat greater amounts of duck weed and use it more efficiently than exotic pigs such as those of the Large White breed
- Duck weed grown in ponds fertilized with biodigester effluent would be a satisfactory source of supplementary nutrients, especially protein

Decisions that had to be made in planning the experiment concerned the selection of the:

- basal diet,
- breed and age of the animals,
- design of the metabolism cages
- feeding system.

Sugar cane juice was chosen as the basal diet because, being composed almost entirely of soluble sugars, with zero fibre, it would not contribute to digesta fill, thus leaving "room" for the "bulky" duck weed; and being almost 100% digestible would contribute minimum amounts of faeces of both "dietary" and "metabolic" origin. The fact that it contains only 1% protein in the dry matter also meant that almost all the dietary protein would be supplied by the test supplement - the duck weed.

It was decided to work with recently weaned pigs of the Mong Cai and Large White breeds and the crosses of the two. In fact, because of severe difficulties encountered in adapting the purebred exotic pigs to the duck weed, the experimental findings were confined to the Mong Cai and their crosses.

Metabolism cages are traditionally designed with the primary objective of achieving an efficient separation and collection of the urine and faeces, to which end the animals are restrained by bars and partitions so they are forced to face in only one direction and have minimal opportunity to move around. The stress this causes usually results in less than normal feed intakes during the period the animals are in the cages. For the present study, it was decided to break with tradition and design the cage from the outset taking into account the need to provide a comfortable environment in which the pig could move freely.

Traditional methodology for doing balance trials with animals usually requires that feed offered is restricted so as to minimize selection and avoid differences between feed offered and refused. A feeding system comprising a liquid (cane juice) and a high moisture, voluminous supplement (duck weed) raises other questions (to mix or not to mix? to restrict, and if so on what basis?). As nothing is known about the relative palatability of fresh duck weed when fed with sugar cane juice, it was decided to make both the feeds available on a simulated free choice basis, offering each feed several times per day but withdrawing it between successive meals.

MATERIALS AND METHODS

Location

The experiment was carried out at the "Finca Ecologica" on the University Campus (UAF-University of Agriculture and Forestry, Ho Chi Minh City), a small farm established by one of the authors (TRP) to demonstrate integrated farming systems with perennial crops, multi-purpose trees, local breeds of livestock, low-cost plastic biodigesters and duck weed ponds. The area is close to sea level with ranges in temperature from 24 to 38°C, and relative humidity in the range 40 to 100%.

Animals

Four Mong Cai male piglets (5-10 kg) were obtained from the local market, four Large White male piglets (9-14 kg) from a nearby State farm and four Mong Cai*Large White piglets (2 male and 2 female) (12-17 kg) from a litter (Mong Cai mother; LW sire) born at the farm.

Metabolism cages

The cages were made from bamboo fixed to a wooden frame in a composite unit (2.8 m length and 0.9 m wide) for 4 animals. The floors were composed of lengths of bamboo poles of 1-2cm diameter with 1 cm spacing to facilitate passing of the faeces. The cages were fitted with automatic water drinkers and the cane juice and duck weed were offered in ceramic dishes. Area per pig was 0.5m² (70*70cm) and the divisions of half bamboo sections were 50cm high. The faeces collector, suspended 5cm below the floor, was a rigid sheet of plastic net used traditionally for sealing windows against entrance of insects. Urine fell through the net and was collected over a sheet of polyethylene suspended in the form of a shallow"V" with the lowest point emptying into a filter placed in a funnel suspended over a plastic bucket. (See plate 1)

Two units were constructed. The total cost each unit for 4 animals (materials and labour) was US$60.00.

Experimental design and treatments
The breed groups were put into one of the cage units in successive periods (Mong Cai and crosses). The purebred exotics were housed in the second unit so as to prolong the period of adaptation, but even this was insufficient (see next section). As the relative amounts of cane juice and duck weed that were consumed varied among animals, regression analysis was used to describe treatment effects, using the proportion of diet dry matter consumed as duck weed as the independent variable.

Diets and feeding system
The sugar cane was crushed every morning using a 3-roll mill and a buffalo to provide traction. The average extraction rate was 50 litres from 100 kg of cane stalk. Sugar cane was purchased from local farmers at 2-3 week intervals and kept under shade until it was processed. Daily observations of brix values of the juice showed negligible change in this parameter during storage periods of up to 4 weeks. The duck weed was harvested daily from the experimental ponds in the farm fertilized with biodigester effluent (Rodriguez et al 1996). When supplies from these were insufficient it was purchased in the market. The supply for one day was mixed before preparing individual feeds. During the first 5 days of the adaptation period both cane juice and duck weed were offered ad libitum. For the rest of the adaptation period and during collection, the sugar cane juice and duck weed were offered in separate containers in discrete meals at frequent intervals (cane juice at 12.00, 15.00, 18.00, 20.00 and 22.00 h; duck weed at the same times with additional meals at 07.00 and 10.00h). The juice was removed between meals and during the night, while the duck weed was available continuously

The pigs had free access to water from automatic drinkers strategically located outside the cages to avoid leaks into the faeces or urine.

Measurements
During the experimental period intakes of sugar cane juice and duck weed were measured daily (by weighing amounts offered and refused). Samples of sugar cane juice offered and residues were collected daily to measure the brix content (total dissolved solids) and the N content. Samples of duck weed offered and refused were collected daily for DM determination and a sample of the offered duck weed was analysed for N. Dry matter was determined by weighing before and after drying for 48 hr in an oven at 100°C and nitrogen by Kjeldahl (Tec) (Table 1). Samples of duck weed, especially the refusals, were analysed immediately to get accurate data, because when the samples were stored in a refrigerator there were obvious physical changes in their appearance and it was considered this might affect the results.

Urine was collected and weighed daily and H_2SO_4 was used to keep the pH below 4 in order to preserve the N. The total daily quantities per piglet were stored in a large bucket until the end of the period when the contents were mixed and a representative sample taken to analyse for N. Faeces were collected and weighed daily. The total amount of faeces/piglet was stored in a freezer (-18°C) and at the end of the period was mixed, ground and representative samples taken for analysis of N (on the fresh faeces) and for dry matter. Brix of the cane juice (total dissolved solids) was measured with a hand refractometer.

RESULTS AND DISCUSSION

Data on composition of the duck weed and the sugar cane juice are shown in Table 1. The values of 31.3 and 35.3 % N*6.25 in the duck weed dry matter are in the median range of values reported by Leng et al (1995) and Rodriguez et al (1996). Brix readings of 19 and 21° in the mixed cane juice indicate close to optimum values for this parameter.

Individual values for the experimental parameters for each pig in each breed group are shown in Annex table 1. Relationships between the percentage of diet dry matter as duck weed (X) and digestibility and N metabolism parameters (Y) were derived (Figures 1 to 6) for the combined data for the 2 breed groups (8 pigs) and expressed as linear equations:

- DM digestibility (% apparent) = 96.9 - 0.356±0.097X (r^2 = 0.69) .....(i)
- N digestibility (% apparent) = 60.4 - 0.290±0.094X (r^2 = 0.61) ....(ii)
- N balance (g/day) = -0.45 + 0.11±0.018X (r^2 = 0.96)...... . ...(iii)
- N retained as % of N digested = 28.5 + 0.710±0.14X (r^2 = 0.80) .....(iv)
- N retained as % of N intake = 16.1 + 0.618±0.11X (r^2 = 0.85)...... ... (v)
- N*6.25 as % of diet DM = 2.15 + 0.310±0.020X (r^2= 0.98).............(vi)

All the regression coefficients were significantly different from zero. Agreement between the two breed groups was sufficiently close to justify the decision to derive the regressions from the combined data.

It can be inferred from equation (i) that with no duck weed in the diet the DM digestibility would be 97%, which is in agreement with the fact that sugar cane juice is comprised almost entirely of soluble and digestible sugars. With 100% duck weed the prediction is a DM digestibility of 61% which also appears a reasonable estimate on the basis of its mode of growth and composition, relative to other leafy materials of tropical origin (Solarte et al 1994). Bui Huy Nhu Phuc et al (1995) reported a DM digestibility for a mixture of cassava root meal (57%) and dried cassava leaves (40%) of 73%. Comparable data in this experiment (40% duck weed of diet DM) would be 83%.

The apparent digestibility of the N of the mixtures of juice and duck weed was in the range 63 to 73% (ii). Apparent N digestibilities, comparing our data with those of Bui Huy Nhu Phuc et al (1995), are 72% (40% duck weed in the diet) and 27.7% (40% cassava leaf meal in the diet).

The N balance (g/day) increased linearly with increasing duck weed in the diet (iii), which was to be expected in view of the high digestibility and good amino acid balance of the duck weed protein (Hillman and Culley 1978). In contrast, in their diet of cassava root meal and cassava leaf meal (40%), Bui Huy Nhu Phuc et al (1995) reported a N balance of only 0.29 g/day, which can be compared with the predicted value (40% duck weed) from our data of 3.95 g/day. The N retained as percent of N intake (41%) and of digested N (57%) are also vastly superior to those reported for cassava leaf meal at similar dietary concentrations (1.2% of N intake and -0.31% of digested N). When cassava leaf meal was only 28% of the diet and soya bean meal was 8%, the comparable values were 19.1% and 42.3%.

Allowing for the higher digestibility of cane juice compared with cassava root meal, it would appear that the duck weed used in our experiment was of superior nutritive value to cassava leaf meal. However, comparisons of the two protein sources using similar basal diets are necessary before definitive conclusions can be drawn.

The original hypothesis concerning the relative merits of indigenous and exotic pig breeds in utilizing diets with duck weed as the sole protein source was not tested adequately, although the fact that the exotic pigs refused to eat the duck weed infers a definite comparative advantage for the Mong Cai breed. However, the crosses of exotic boar (Large White) with Mong Cai, responded similarly to the purebred Mong Cai (Table 2) in terms of intake of duck weed, digestibility and N utilization. We believe that when unconventional feed resources are to be used, it may be important to offer them to pigs at an early stage of their lives and that this will facilitate their acceptance later. In this respect the Large White*Mong Cai crosses had access to duck weed from birth as this was the sole protein source of their mother. In contrast, the exotics had been exposed only to cereal-based concentrates prior to the experiment. It is not known precisely whatthe feeding regime of the Mong Cai pigs prior to purchase had been, although the tradition in the village where they were raised is to feed rice soup and vegetables.

CONCLUSIONS

The results of this preliminary trial with local pigs and their crosses fed a basal diet of sugar cane juice with duck weed as the only protein source indicated that the nutritive value of the duck weed was high in this particular feeding system, and apparently superior to that of cassava leaf meal fed in combination with cassava root meal.

Fifty percent of the Mong Cai pigs and their crosses with Large White were able to consume fresh duck weed in proportions sufficient to provide a diet with more than 10% of protein in the dry matter.

Purebred exotic pigs (Large White) appeared to be less adapted to consume the duck weed and would only eat it when mixed with sugar cane juice, and even then with reluctance. Early exposure to duck weed may be an important factor in later acceptance of this feed.

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Table 1. Mean Values for dry matter and N in offer and residue of duck weed and sugar cane juice in experiments with Mong Cai and Mong Cai *Large White crosses

	MC	MC*LW	SE/Prob
Duck weed			
Offer, % DM	7.11	6.33	±0.24/0.05
Residue, % DM	7.93	6.92	±0.18/0.04
Offer, %N in DM	5	5.65	±0.17/0.03
Offer, N*6.25	31.3	35.3	
Cane Juice			
Offer, Brix	19	20.9	±0.19/0.01
Residue, Brix	18	19.9	±0.28/0.01
Offer, % N in DM	0.32	0.31	±0.019/0.72

Table 2. Comparative parameters of digestion and N metabolism in Mong Cai and Mong Cai*LargeWhite piglets (5-16 kg LW) having free access to sugar cane juice and duck weed (n=4/breed)

	MC	MC*LW	SE/Prob
Duck weed as % DMI	23.8	26.7	±6.4/0.77
Duck weed N as % Total N	77.6	85.7	±5.3/0.32
Digestibility, %			
Dry matter	90	85.9	±1.2/0.07
Nitrogen	67.8	67.7	±1.7/0.94
N retained, %			
N intake	33	30.5	±1.7/0.34
N digested	48.2	44.7	±2.3/0.44

Annex 1. Parameters of digestion and N metabolism in Mong Cai and Mong Cai x Large White crosses

Breed	MC	MC	MC	MC	MC* LW	MC* LW	MC* LW	MC* LW
Exp.	1	1	1	1	2	2	2	2
Pig No.	1	2	3	4	1	2	3	4
LW, Kg	5.65	8	7.3	9.5	13.5	11.6	9.3	12.3
DM (g/d)	256	417	321	346	607	447	423	560
Lemna DM (g/day)	31.00	188.0	91.00	34.00	144.0	156.0	132.0	95.00
Lemna %DMI	12.11	45.08	28.35	9.83	23.72	34.90	31.21	16.96
Dig DM%	94.1	82.6	89.1	95.3	87.8	85.98	80.19	87.90
N int g/day	2.28	10.23	5.32	2.73	9.60	9.80	8.50	6.80
N*6.25% of DM	5.57	15.33	10.36	4.93	9.88	13.7	12.56	7.59
N bal, g/day	0.57	4.65	1.90	0.61	3.20	3.10	3.20	1.55
Nbal% Int	24.82	45.45	35.71	22.34	33.33	31.63	37.65	22.79
%digN	64.10	72.7	67.1	65.8	70.4	72.36	69.80	59.70
Nret%dig	38.82	62.50	53.3	34.04	46.81	44.3	53.84	38.20
N lemn g/day	1.55	9.50	4.58	1.73	8.20	8.80	7.50	5.38
% N as lemna	67.98	92.86	86.09	63.37	85.42	89.8	88.24	79.12

Figure 1. Relationship between duck weed intake as % of Total DMI and dry matter digestibility in Mong Cai piglets and MC*LW (5-14)kg Lwt) with free access to sugar cane juice and duck weed

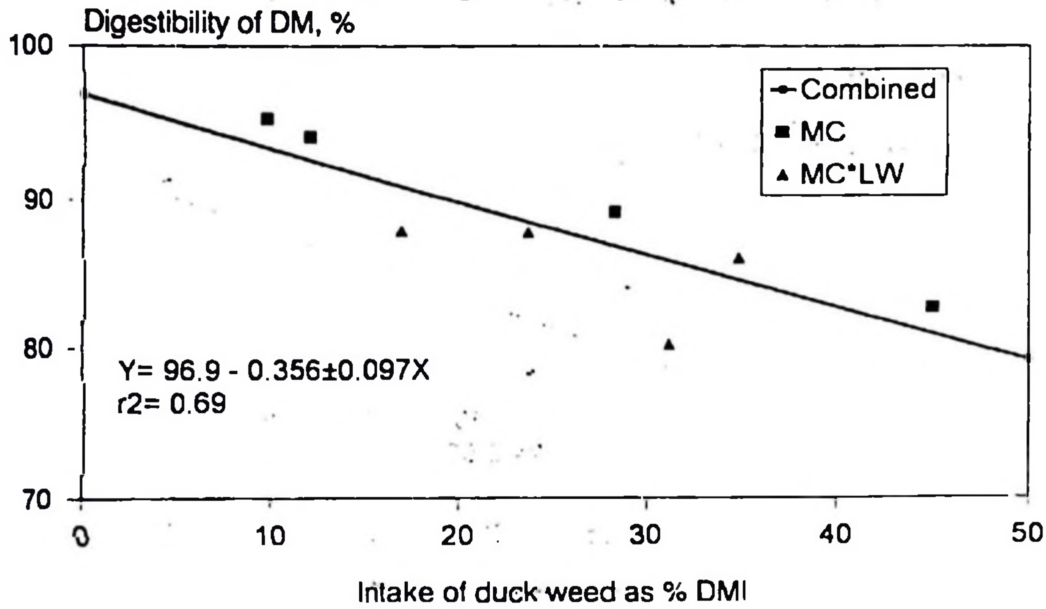


Figure 2. Relationship between intake of DM as duck weed and N digested in Mong Cai and MC*LW piglets (5-14 kg LW) with free access to sugar cane juice and duck weed

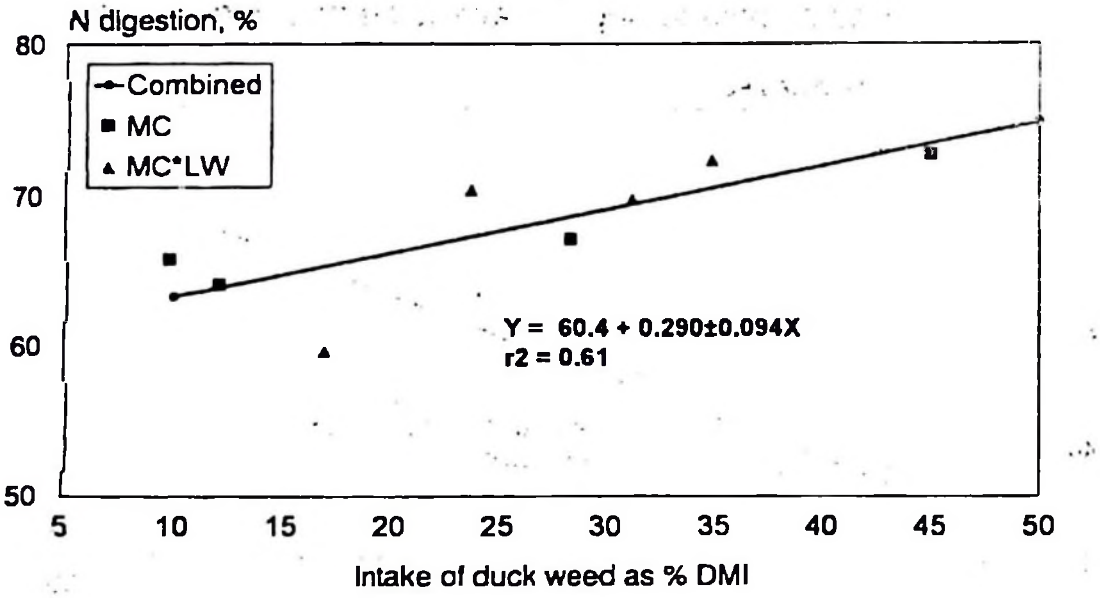


Figure 3. Relationship between duck weed intake as % of Total DMI and Nitrogen Balance in Mong Cai and MC*LW piglets (5-14kg LW) with free access to sugar cane juice and duck weed

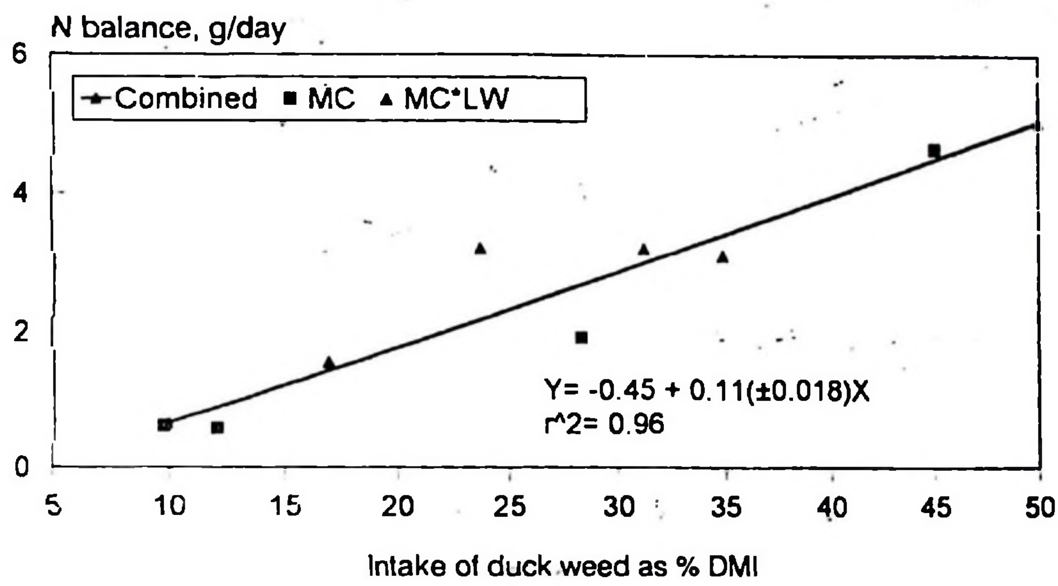


Figure 4. Relationship between intake of DM as duck weed and N retained as % digested in Mong Cai and MC*LW piglets (5-14 kg LW) with free access to sugar cane juice and duck weed

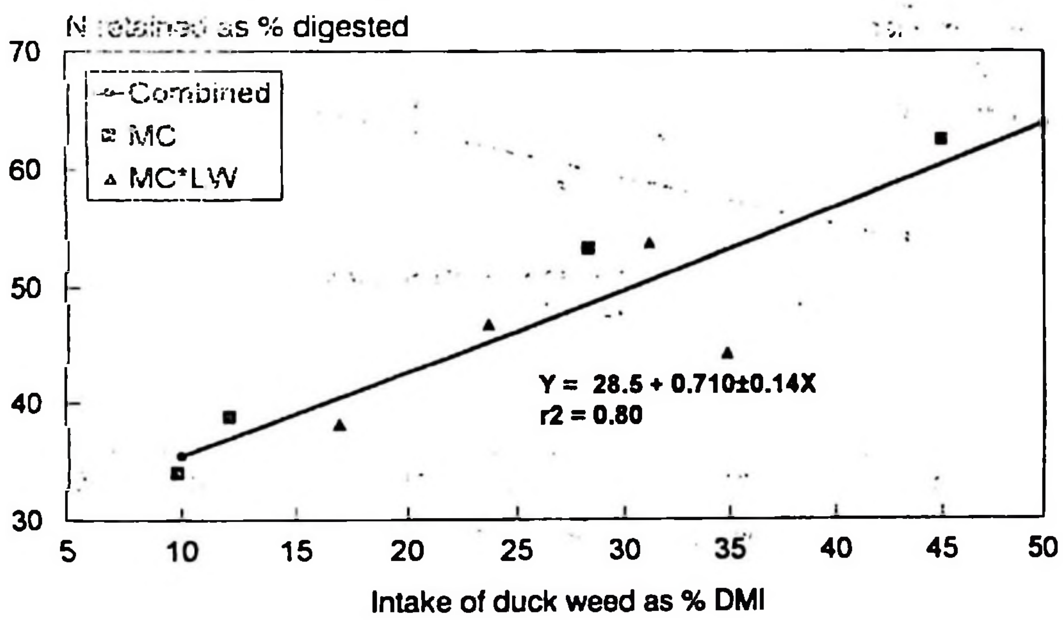


Figure 5. Relationship between intake of DM as duck weed and N retained as percent of N intake for Mong Cai and MC*LW piglets (5-14 kg LWt) with free access to sugar cane juice and duck weed

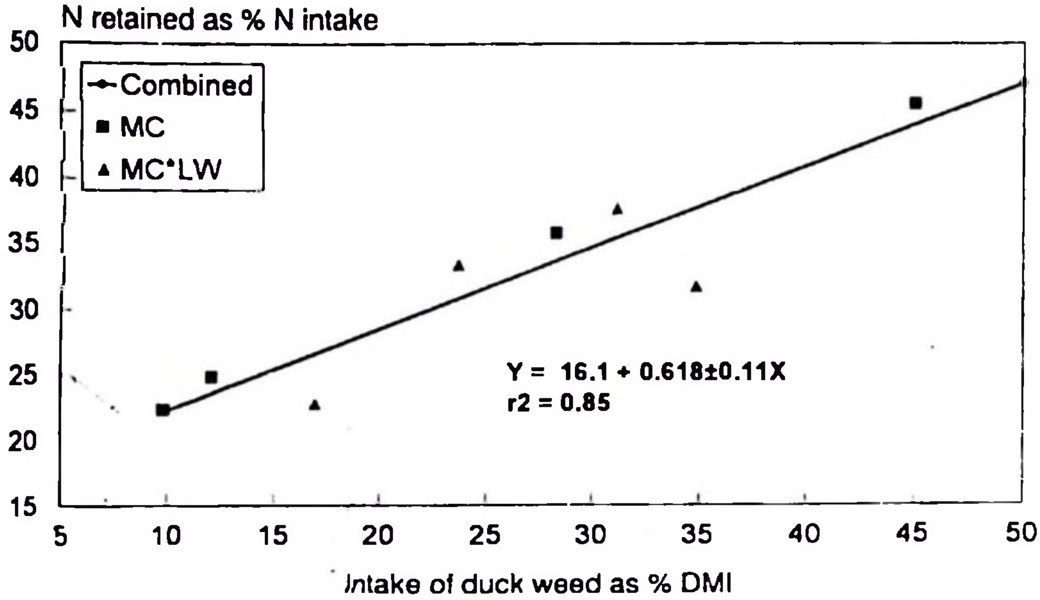


Figure 6. Relationship between intake of DM as duck weed and N retained as percent of N intake for Mong Cai and MC*LW piglets (5-14 kg LWt) with free access to sugar cane juice and duck weed

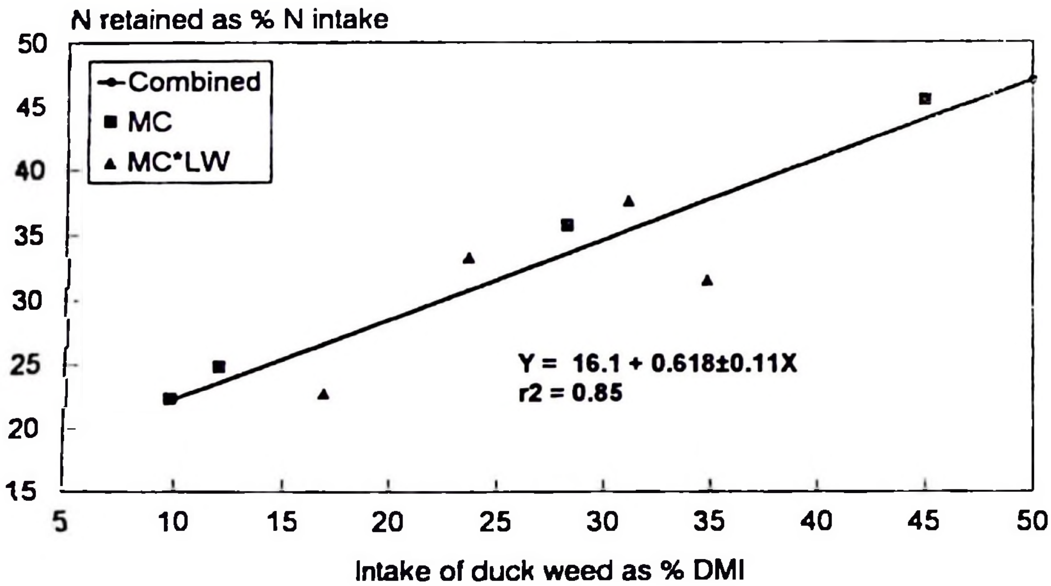
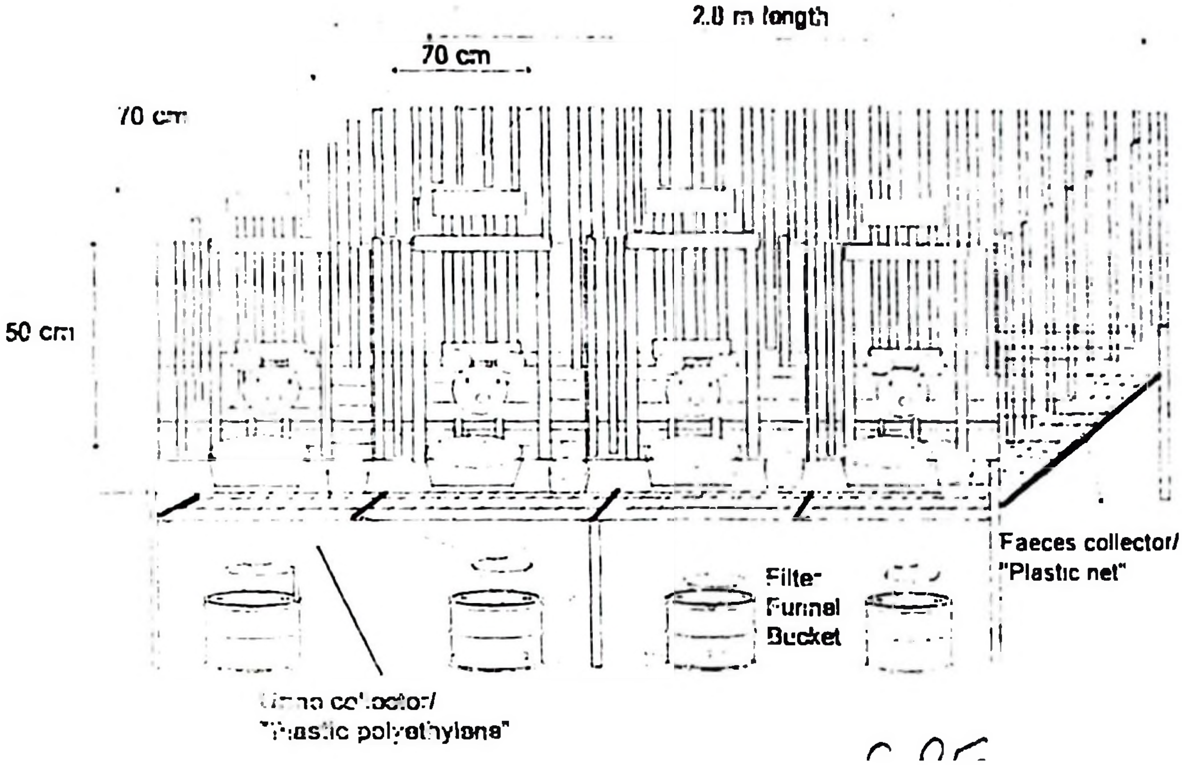


Plate 1. Digestibility cages made from bamboo



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