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Working Paper 1 – A typology of brackish-water pond aquaculture systems in the Philippines

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ABSTRACT

Aquaculture in the Philippines is a long-standing activity but has witnessed relatively recent, rapid, technical change with the introduction of hatchery technology and commercial feed-mills changing the production possibilities for a fishpond operator. We are confronted with a diversity of aquaculture practices in the coastal areas of the Philippines, with new technologies being incorporated into more traditional systems. As a first step to understanding the sector, we therefore present a typology of farming systems with the motivation of generating domains (farm "types") over which we can compare performance on a number of indicators. Our typology, restricted to brackish-water pond systems, is constructed using multivariate methods (principal components analysis, cluster analysis). Eight variables are used relating to the management of the farm across all the major factors of production. A stratified net sample of 136 observations provides the data for the analysis, from a farm-level survey carried out between January and June 2003 in the two main brackish-water production regions in the Philippines. We define five farm types from this analysis. In later work we will show how the use of this typology can be used for comparative study of economic, social and ecological performance at the farm-level.

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This paper is dedicated to the memory of Rose-Glenda Alcalde

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1 Introduction

The central proposition underlying work on typologies of farming systems is that farms are similar or identical to other farms of the same type (according to particular characteristics of interest) and that they are dissimilar to farms of other types. This follows from Derek Byerlee's idea (Byerlee *et al*, 1980) of "recommendation domains", such that policy statements made regarding one member of a domain are likely to hold for the other members of the domain. While interesting as an end in itself, a typology increases the likelihood that analysis of, for example, productivity (within domain) or comparative study (between domains) will be conducted properly (Shang, 1981).

For example, we might expect technical efficiency (or any other indicator of performance) "within domain" to be explained in the most part by managerial competence. In contrast, differences in the level of technical efficiency "across domains" might be accounted for by underlying differences in the nature of the technology. The conclusions for policy of determining differences within domain, as opposed to differences across domains, are very different. A lack of managerial competence might be addressed by increased investment in government extension services with respect to particular production techniques within domain. Alternatively, apparent differences in technical efficiency that are actually driven by inherent differences (e.g. in production risk) in the nature of the techniques used across domains.

There are numerous sets of criteria that can be used to classify aquaculture systems, drawn from technical, geographical, economic, ecological and social perspectives. Shang (1981) identifies ten criteria by which aquaculture systems could be conceptually divided. Some of Shang's criteria are nominal (e.g. nature of enclosure). Highlighted in bold are the categories of specific nominal criteria that serve to define the scope of the present study; i.e. *only aquaculture systems producing human food products in ponds filled with standing brackish-water of a tropical temperature are included in our survey*. In the Philippines however, this apparently already narrow sub-set of aquaculture systems contains a great heterogeneity in Shang's other categories.

We argue here that some of Shang's other criteria are not qualitative but quantitative. Shang has produced quasi-qualitative criteria by either imposing categories on a quantitative scale (e.g. monoculture/polyculture, water temperature) or by simplifying a complex combination of quantitative data in different dimensions (e.g. level of management intensity[1]). In these cases there are not the same fundamental shifts between categories as for truly qualitative criteria.

The objective of the typology work here is to tackle this heterogeneity using multivariate statistical methods. Most fundamentally however, we are interested in representing the current range of techniques employed in the Philippines. In later work we will consider the "farm types" established here as possible options for the use of the brackish-water land area and use them in the construction of models of the farm-level trade-offs between different policy objectives. Examples of these objectives are to maximise economic efficiency, maximise social acceptability and to minimise ecological impact.

The structure of this paper is as follows: in section 2 we further highlight the need for clarity with respect to production techniques under appraisal and why a typology is necessary; in section 3 we outline the methods we will employ in analysing our data, and refer to the literature on related studies; in section 4 we describe our data and the analyses; section 5 has our results and interpretations; section 6 examines the geographical distribution of farm types within our study regions; section 7 concludes.

[1] We use the term production intensity from hereon, in the same way Shang uses management intensity. This is to avoid confusion with the level of managerial or supervisional input the farm requires, which might also be considered "management intensity".

Table 1 – List of criteria by which aquaculture grow-out systems might be classified (from Shang, 1981).

Criteria	Category
Purpose of Culture	**Human food**
	Improvement of natural stock
	Sports and recreation
	Ornamental fish
	Bait
	Industrial products
Nature of enclosure	**Pond culture**
	Cage and pen culture
	Raceway culture
	Raft culture
	Closed high-density culture
	Sea ranching
Sources of fry	Natural waters
	Captured gravid females
	Hatching
Level of management intensity	Extensive
	Semi-intensive
	Intensive
Number of species stocked	Monoculture (single species)
	Polyculture (more than one species)
Water salinity	Fresh water
	Brackish water
	Marine water
Water movement	Running water
	Standing water
Water temperature	Cold water
	Warm water
Food habit	Herbivorous species culture
	Omnivorous species culture
	Carnivorous species culture
Combination with agriculture production	Rice-fish farming
	Poultry-fish farming
	Pig-fish farming

2 Highlighting the Problem – Measuring Production Intensity

> *"'Intensity' relates to resource utilization (land, water, capital, labour, seed, feed, fertilizer and fuel) and different systems may be more or less intensive depending on which resource is considered. It is important to understand the use of all these resources if a thorough assessment of the sustainability of different kinds of shrimp culture is to be made."* (World Bank, 2002)

There are many studies that classify aquaculture systems using a measure of production intensity. However, the choice of variable or combination of variables with which to represent the concept of production intensity is not a trivial issue. The most important variables are perhaps stocking density, feeding rate and fertilizer application rate.

For monoculture of tiger prawn *Penaeus monodon*, Clay suggests stocking densities of greater than 200,000 pieces/ha for intensive systems, 25,000 – 200,000 pieces/ha for semi-intensive systems and less than 25,000 pieces/ha for extensive systems (Clay 1996 - cited in World Bank, 2002). However, the use of stocking densities alone makes comparison between polyculture systems, or between monocultures of different species, problematic. This is because different species have different habits of feeding, different body sizes at stocking and at maturity, different survival rates and patterns of natural behaviours. Given that the brackish-water pond production in the Philippines is a long-standing activity (Primavera 1995) that has evolved from traditional systems of polyculture with natural recruitment, there is a need to move away from reliance on the use of stocking density to characterize systems.

Using the feeding rate to describe the systems has distinct advantages as Ravagnan (1981) advocates:

> *"If we accept the concept that it is not the degree of crowding, but rather the energy derivation from the feed, i.e. the feed regime, which distinguishes the various methods of farming (Ravagnan, 1980), we consider: extensive the farm that takes its feed exclusively from the environment; intensive the one that instead takes it exclusively from outside sources; and semi-intensive the one that exploits the environment but integrates it with feed coming from outside sources. The production technologies available to us range around these three methods".* Ravagnan (1981, p.65).

This is an ecological classification and is an appealing approach from theoretical and practical viewpoints. The overall energy balance of the system gives important insights for those examining the food security implications of aquaculture and for ecologists studying the effect of nutrient enrichment on coastal waters. From a practical viewpoint, the problem of equivalence across species is lost and so feeding rate can be used for monoculture or polyculture systems.

In generating a measure of "farming" (or "production") intensity, there are both definitional and measurement issues. The most accurate definition probably comes from an economic perspective and argues that intensity is the use of variable inputs (e.g. fry, feeds, fertilizers) in relation to land. However, as with economic measures of partial productivity, the inputs can be substituted for one another to some extent, so that measuring one input cannot be totally satisfactory. It is therefore important to employ a multivariate approach to classification, which allows us to look at the particular sets of combinations of inputs that currently define production practices.

3 A Multivariate Approach to Classification

3.1 Factor Analysis

Factor analysis belongs to a group of models known as latent variable models. A latent variable is a concept that cannot be directly measured such as human "intelligence" or farming "intensity", that theory suggests is correlated to a number of specific tests (in psychology) or measurable features of systems (in farming systems research). Factor analysis is actually a group name for a range of specific statistical techniques used on multivariate datasets to explain either patterns of covariance or correlation in a set of observed variables, as function of a limited number of underlying factors.

In factor analysis there are no dependent and independent variables. Rather a matrix of covariance scores (for the specific method of "Principal Axis Factoring") or correlation coefficients (for "Principal Components Analysis") is used as the basis to explore how all the variables are related to underlying factors. Factor analysis yields interesting information as an end in itself – it gives us information on variables that are not directly observable. However, its purpose is also commonly to transform a multivariate dataset with many variables and correlations between the variables (multi-colinearity), to a new smaller set of underlying factors. It is considered a “data reduction” technique in this regard. Useful properties of these factors are that they are orthogonal to each other in factor space and are linear combinations of the original variables[2].

If the data set is well suited to factor analysis, and the original variables are well chosen, the construction of factors will occur without significant loss of information. Following this, factor scores for the individual observations (farms), showing the position of the observation in factor space (which can be positive or negative) can be calculated. Factor scores should then be used as a new dataset for carrying out cluster analysis. It would be inappropriate to carry out cluster analysis on the original dataset due to multi-colinearity in the original variables, which would effectively create weights in any clustering algorithm. Factors are orthogonal and therefore this problem is resolved. We can use cluster analysis to calculate the degree of similarity or dissimilarity between individual farms, in terms of their scores on the underlying factors.

3.2 Cluster Analysis

Cluster analysis is another exploratory technique where we do not have *a priori* hypotheses (in this case, with respect to the number or properties of the farm types) but are examining the structure of the data. It is a multivariate technique for classifying observations into groups (clusters). In the case of farming systems, ultimately each farm is unique in some respect. However, by using the factor scores we obtain in carrying out principal components analysis, we can see how similar each farm system is to the other individual farming systems in our sample.

The objective of cluster analysis in the present case is to generate solutions that maximize similarity within groups of farms so that we might label each group as a particular farm “type”. The term cluster analysis actually covers a number of different algorithms and measures of distance that can be employed in generating a typology. We employ Ward’s method (Ward, 1963) and use squared Euclidean distance in multidimensional space.

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[2] Detailed treatments of this technique can be found in Comrey and Lee (1992). A more accessible introduction is provided by Kline (1994).

The geometric distance in multidimensional space (in this case 3 components – see section section 5.1 below) is known as Euclidean distance. However, we employ squared Euclidean distance so that progressively greater weight will be placed on farming systems that are further apart. Squared Euclidean distance is computed as:

$$\text{distance}(x,y) = \Sigma_i (x_i - y_i)^2$$

where x and y are two observations (farms) and *i* relates to each of the dimensions.

Ward's method of cluster analysis is one of a family of specific algorithms known as hierarchical (agglomerative) cluster analysis. These algorithms start with a set of individuals[3] (in our case farms), and begins by attempting to identify the two individuals with most similar scores. At this step in the analysis, these two individuals are merged to form a cluster. This cluster is treated as a single individual in the next step in the analysis, thereby reducing the number of individuals to be considered in the second step of the analysis by one. This process continues, with the number of individuals decreasing, and the number of clusters increasing. Therefore, as the analysis proceeds, the statistical software merges clusters rather than just individuals at each step (Stevenson, 1989).

Algorithms differ in the way in which the clusters are formed at each stage. Ward's method operates by testing which merger at each stage produces the least reduction in the overall *within* cluster squared distances. The output from any hierarchical cluster analysis is in the form of a dendrogram, showing the history of the cluster mergers from all individuals in the sample (i.e. all farms unique), up to a single cluster (i.e. all farms of the same "type"). The point at which we 'cut' the dendrogram will determine the number of clusters (i.e. farm "types") produced.

3.3 Previous Applications to Agriculture and Aquaculture

Kobrich, Rehman and Kahn (2003) report on two applications of multivariate techniques to the problem of classifying agricultural system types; one for Chilean

[3] Cluster analysis, as well as factor analysis, both have strong traditions in the psychometric literature. It is only relatively recently that these methods have been adopted by the farming systems research community.

peasant farming systems and one for wheat-rice farms in Pakistani Punjab. Both of these typologies were based on primary data collection surveys in their study regions.

Within aquaculture research, Coche (1982) and Muir (1995) present uni-dimensional guides for classification of different aquaculture systems, using production intensity – a variable that is itself multidimensional as we have outlined. Therefore, Michielsens *et al* (2002) represents the first application of factor analysis and cluster analysis to yield an empirical typology of aquaculture systems. In classifying carp farming systems across Asia, Michielsens *et al* (2002) used the following 12 variables: Area of the aquaculture facility (ha); Ratio of aquaculture facility to total farm area (%); Water added during the culture period (cm / month); Purchased inorganic fertiliser (kg / ha /yr); Total organic fertiliser (10^3 kg / ha / yr); Ratio of organic fertiliser collected (on or off-farm) to total organic fertiliser used (%); Total feed added (10^3 kg /ha /yr); Number of fish species cultivated; Stocking density (10^4 fishes / ha); Total labour (10^2 days / ha /yr); Ratio of family labour to total labour (%). Data came from a NACA/ADB farm-level survey.

Michelsens *et al*'s analysis suggests six "types" of carp farming system in Asia, which they name: Super-intensive, Intensive, Specialised semi-intensive, Specialised semi-extensive, Integrated semi-intensive, Integrated semi-extensive. The typology is put to use to examine the resource-use efficiencies of different farm types. We follow the lead shown by Michelsens *et al* by applying the multivariate techniques factor analysis and cluster analysis to data collected from a farm-level survey in the Philippines.

4 Farm-level Survey

4.1 Sampling

The two top regions for brackish water pond aquaculture production, regions 3 (Pampanga, Bulacan, Bataan and Zambales) and 6 (Iloilo, Capiz, Negros Occidental and Aklan), were chosen as study areas. The sample was stratified by farm size and by province, based on census data from 1997 provided by the Philippine Bureau of Agricultural Statistics (BAS). A breakdown of the net samples used in the analysis is given in appendices 1a and 1b.

Interviews with fishpond "operators" (those who invest capital, take the financial risks and gain the profits) and "caretakers" (salaried supervisors for those farms where the operator does not live on the farm)[4] were carried out on representative samples of fish farms from regions 3 and 6 between January and May 2003.

A net dataset comprising 11 variables and 137 observations (farms) was initially compiled after processing the farm-level interview data was complete. One farm observation was subsequently dropped from the dataset after test runs with principal components analysis and subsequent cluster analysis found it to be an outlier[5]. 136 farms were retained in the final dataset.

4.2 Motivations for choosing the variable set

The typology is based on technical aspects of the farming systems. The choice of the final list of variables, from a large dataset compiled during the farm-level survey, was motivated by experience gained in carrying out the interviews. Most of the farms are polyculture systems, but different priorities dominate on different farms. Operators are generally either orientated towards *prawn production* or towards *milkfish production*. This is supported by farmer testimonies and by Pierre Morissens, a researcher with CIRAD (Cooperation Internationale en Recherche Agronomique pour le Developpmente) with more than six years experience of working with farmers in the study area. Crabs and tilapia will sometimes be added as secondary species, for the purposes of aeration, or opportunisitically if the market and environmental (i.e. salinity) conditions are good, but these are not of fundamental importance to the operators and are not given "special treatment" on the farm.

None of the farms in the sample operated at a sufficiently high level of intensity to require mechanised aeration, in the form of paddlewheels, and in general the level of capital investment on the farm is relatively low. Therefore, the main differences between farms in terms of the use of factors of production (land, labour, capital)

[4] For a treatment of the nature of this relationship, see Stevenson *et al* (2003)

[5] The farm represented a unique cluster with anomalously large Euclidean distance in the cluster solution from all other farms. This is likely to be due to the fact that it is a small farm (0.17 ha) and so any accuracy problems in the data for that farm are magnified when units/ha/yr are calculated.

would seem to be *the relative importance of land and labour*. A degree of substitutability between these two factors might be expected in the production function for these farms.

With these key ideas in mind, the following 8 variables were chosen for principal components analysis:

farmsize	Farm size (ha)
inorg	Total inorganic fertiliser applied (kg/ha/yr)
organic	Total organic fertiliser applied (kg/ha/yr)
totlabor	Total labour input (man days/ha/yr)
commfeed	Ratio of commercial feeds to total feeds added (%)
sugposd	Stocking density of tiger prawn (Fry/m^2)
bangussd	Stocking density of milkfish (Fry/m^2)
totfeeds	Total feeds added (kg/ha/yr)

The raw data reported by farmers were in a variety of local units and over different periods. The emphasis in the data collection was placed on getting credible data, rather than on convenience for analysis. Therefore a lengthy process of sorting and coding the data was required.

4.3 Factor Model - Testing for appropriateness

The underlying assumption of a factor model (the existence of a few factors that underlie variability in the data) in carrying out a Principal Components Analysis (PCA) may be more or less appropriate depending on the nature of the data. Two widely used statistics to determine the validity of using a factor model on a data are the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The results of both of these tests for the current data set are given in table 2 below.

Table 2 – KMO and Bartlett's statistics for the factor model data set

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.671
Bartlett's Test of Sphericity	Approx. Chi-Square	118.223
	df	28
	Sig.	.000

Bartlett's test is used to test the null hypothesis that the variables are uncorrelated in the population (Hair *et al*, 1998). For this test, the population correlation matrix is an identity matrix. Bartlett's test uses a chi-square transformation of the determinant of the correlation matrix and, with the current dataset the null hypothesis can be rejected, thereby giving no reason to question the validity of using a factor model on the data.

The KMO statistic compares the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. While there is no absolute cut-off or statistical tests for the value of the KMO statistic, a value of 0.7 and above is desirable, but values of 0.5 and above are tolerable. Essentially, a small value for the KMO would suggest that the correlations between pairs of variables cannot be explained by other variables (Sharma, 1996).

In addition to statistical tests outlined above, the inspection of the correlation matrix for the dataset should show a significant number of correlated pairs of variables of around 0.3. This final rule of thumb for the appropriateness of the dataset to factoring is less satisfactorily resolved in this case than the formal statistical tests. There are many pairs of correlations but usually in the range 0.2 to 0.25. It is therefore important that all the variables show high communality after the extraction (the amount of variance in each variable explained by the factor model) and that the components are easily interpretable. The correlation matrix for the 8 variables is given in appendix 2.

5 Results

5.1 Factor Extraction

A PCA extraction was carried out on the dataset in SPSS using the correlation matrix and standardised variables (i.e. with mean = 0 and standard deviation = 1). Communalities for the 8 variables are sufficient (the extraction accounts for at least half of the original variance for most of the variables) and are shown in table 4 below.

There is a degree of subjectivity with regard to the number of factors that should be extracted. Common stopping rules are: to stop when eigenvalues go below 1 (see table 3 below); and the scree test (to extract at a noticeable step change in the scree plot – see appendix 3). Of these, the scree test is inconclusive (3, 4 or 5 components could be defended) and so the eigenvalue rule is used, which suggests that 3 components should be extracted.

Table 3 – Variance explained by the 3 principal components

Component	Eigenvalue	% of Variance	Cumulative %
1	**2.235**	**27.941**	**27.941**
2	**1.328**	**16.606**	**44.546**
3	**1.067**	**13.341**	**57.887**
4	.810	10.121	68.008
5	.781	9.759	77.768
6	.659	8.233	86.001
7	.632	7.897	93.898
8	.488	6.102	100.000

Table 4 – Communalities, the % variance each of the 8 original variables explained by the 3 component extraction

	Initial	Extraction
Zscore(FARMSIZE)	1.000	.585
Zscore(INORG)	1.000	.436
Zscore(ORGANIC)	1.000	.557
Zscore(TOTLABOR)	1.000	.598
Zscore(COMMFEED)	1.000	.459
Zscore(SUGPOSD)	1.000	.599
Zscore(BANGUSSD)	1.000	.630
Zscore(TOTFEEDS)	1.000	.767

Table 5 – Component solution matrix

	Component		
	1	2	3
Zscore(FARMSIZE)	.250	**-.668**	.275
Zscore(INORG)	**.617**	.187	-.144
Zscore(ORGANIC)	**.690**	-8.104E-02	.273
Zscore(TOTLABOR)	-.198	**.668**	-.334
Zscore(COMMFEED)	**.568**	.326	.174
Zscore(SUGPOSD)	**-.638**	3.538E-02	.437
Zscore(BANGUSSD)	**.642**	.352	.307
Zscore(TOTFEEDS)	-.367	.403	**.685**

5.2 Interpreting the Component Loadings

The correlations between the observed variables and the underlying factor model are called the component loadings. Any given variable should only load significantly on one or possibly two components, but any given component may have several variables that load on it. The components should be interpretable in line with hypotheses held prior to the analysis. Table 6 below (from Hair *et al*, 1998) gives the guidelines for identifying significant component loadings based on sample size. In this analysis, significance is based on: α=0.05, a power level of 80 percent, and standard errors that are assumed to be twice those of conventional correlation coefficients. With our sample size of 136, we can consider factor loadings of around 0.48 and above to be significant.

Factor Loading	Sample Size Needed for Significance
30	350
.35	250
.40	200
.45	**150**
.50	**120**
.55	100
.60	85
.65	70
.70	60
.75	50

Table 6 - Guidelines from Hair et al (1998) for identifying significant factor loadings based on sample size.

Referring to the factor loadings in the solution in table 5, we can interpret and name the components according to those variables that load significantly on that component[6]. Statistically significant loadings are marked in bold.

5.2.1 Component 1 – "Specialisation"

This component describes the orientation of the production system towards either of the two main crops: prawns or milkfish. The stocking density of milkfish fry (BANGUSSD) is positively loaded on this component. In addition, however, variables for both kinds of fertilizer (INORG and ORGANIC) load significantly positively on this component. This is because inorganic and organic fertilizers are used to culture natural food in the grow-out ponds ("lab-lab"[7] and "lumot"[8]) and milkfish can feed on this natural productivity throughout their life-cycle. In the cases where the operator wishes to fatten the fish prior to harvest ("finishing") or increase their growth rate due to low water temperature or low density of lab-lab, then commercial feeds are added. This explains the significant loading for the ratio of commercial feeds to total feed added in the year (COMMFEED), because only high quality commercial feeds are used to supplement the natural productivity of the pond ecosystem.

Commercial feeds are used much more sparingly in prawn polyculture systems. Commercial feeds are expensive, and increasingly so. For an operator to use commercial formulated prawn feeds in polyculture would make little economic sense. The feed would tend to be eaten by the secondary species in the pond, the prices of which attract only a fraction of the price of the prawn.

Commercial feeds are often employed by prawn polyculture operators during the critical nursing period (usually up to a month in duration), where the recently hatched prawn fry are separated from the rest of the species on the farm to avoid mortality

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[6] The solution given is unrotated. Rotations, such as Kaiser's varimax rotation (Kaiser, 1958), are sometimes used in interpreting component loadings. However, rotations represent a simplification of the underlying component structure that in our case is not required – the results are interpretable as they are.

[7] Lab-lab is the Filipino term for a dense mat of microbenthic organism communities, composed of algae and diatoms, that rests on the pond floor (Sumagaysay-Chavoso & San Diego-McGlone, 2003).

[8] Lumot is the Filipino term for filamentous algae.

from predation. However, the quantities of commercial feeds used in this period ("Fry Mash") are small, due to the minute size of the fry.

Additionally, milkfish experience relatively low rates of mortality once they have brought through their nursing period, whereas prawns tend to be much more prone to shocks in the pond ecosystem. They are more sensitive to salinity changes, temperature changes and viral outbreaks (Kautsky, Ronnback *et al.* 2000). Operators can make the decision to add commercial feeds for milkfish during later periods of grow-out, relatively safe in the knowledge that the production risk is low. In many cases, the important component of risk in milkfish monoculture is the fluctuation in price due to the multiple sources of milkfish in the market (i.e. pond culture, pen and cage culture). Operators will often keep the fish at market size until they have agreed a good price in the market before harvesting.

As a corollary, prawn stocking density (SUGPOSD) loads significantly negatively on this component, suggesting that farms that are specialized in prawn production do not stock milkfish at high densities or use large quantities or commercial feeds or fertilizers. Farms with a neutral score for this component are those with no specialization for either milkfish or prawns and are likely to be particularly extensive (i.e. with low stocking densities).

Overall, the component "Specialisation" accounts for 27.9% of the original variance in the set of eight variables.

5.2.2 Component 2 – "Labour vs Land Intensity"

The second component to be extracted has farm size (FARMSIZE) as a significant negative loading and total labour (TOTLABOUR) as a significant positive loading. The component has been named the "Land vs Labour Intensity" because conceptually, farms may lie anywhere on a continuum where land is the major factor of production at one end (those with a negative component score), and labour is used in attempted compensation for lack of land at the other end (farms with a positive component score). This would suggest the possibility of some degree of input substitution between labour and land in the production function..

Overall, the component "Labour vs Land Intensity" accounts for 16.6% of the original variance in the set of eight variables.

5.2.3 Component 3 – "Feed Intensity"

Only one variable loads positively on this component: the total feeding rate (kg feeds / ha /yr "TOTFEEDS"). Prawn stocking density loads positively on this component, but at a level that is not significant at the level $\alpha = 5\%$. The interviews carried out during the survey showed that some farms, particularly prawn-oriented systems, used large quantities of low-quality feeds, particularly small molluscs collected from nearby riverbeds ("gasang", "suso" "agiis"; Cruz, 1997). The major explanation for the evolution of this method of production is the converse of the details given above in relation to milkfish culture. By using low quality feeds of low cost (P1-2 / kg in comparison to P12-20 / kg for commercial feeds) it is possible to minimize the costs of rearing prawns as a strategy to minimize the production risk associated with a given production cycle. The lower growth rates associated with low quality feeds, thereby lengthening the production cycle and extending the possibility of exposure to disease and other shocks, would appear to be more than compensated for by the reduced loss in the case of high mortality.

In these systems, it would appear that a survival rate to adult size of only 2 or 3% would result in a positive gross margin. 5% survival would result in a healthy profit, thus making the polyculture of prawn based on low quality feeds a very economically resilient system in the short to medium term. Longer term, there could be a problem with excessive harvesting of shells from the riverbed. If the cost of these natural resource-based supplemental feeds were to rise significantly, the economic feasibility of these systems would be under threat, in the same way milkfish intensification is under threat from rising commercial feed prices.

The component "Feed Intensity" accounts for 13.3% of the original variance in the set of eight variables.

5.3 Cluster Analysis

The principal components analysis has given us 3 dimensions along which the farms are distributed according to their technical and management characteristics. We can visualise the distribution of the 136 farms in 3 dimensions but the picture is somewhat complex. By carrying out a cluster analysis, we can identify groups of farms that similar to each other and different from farms of other groups. Ward's method (Ward, 1963) allows us to work with distance functions in any number of dimensions.

A cluster analysis was carried out using the factor scores from the 3 principal components over the 136 farms using Ward's algorithm in SPSS. The dendrogram showing a possible cutting line is shown in appendix 4. The number of clusters to choose (i.e. at which point to "cut") depends largely on the purposes of the exercises. In the absence of any a priori expectations as to a "true" number of farm types, we choose the 5 cluster solution. We think that this gives a range of solutions with sufficient level of disaggregation to illustrate the complexity in how fishponds operate. Too much disaggregation, and the farm types would become too numerous, too complicated to understand and too difficult to communicate effectively.

5.4 Cluster solution x Principal Component Scores: "Farm Types"

The next stage is to interpret the results of the cluster analysis. To do this, we cross the cluster solution with the factor scores to see which factors are important in defining each "farm type". Figure 1 below shows the 5 cluster solution in a 3-dimensional scatterplot where the axes are each of the three principal components.

Illustrated in figures 2a-c, are factor scores for the 3 principal components for each of the clusters. This allows us to examine the factors that characterise the farm types. Statistically significant differences between the mean factor scores for each farm type are tested in appendix 5. In addition, we can examine the five farm types according to the original set of 8 variables in shown in table 7 below. From this we can identify the features that define each farm type and name them. This will be the focus of the next section.

Figure 1 – Distribution of farm types in the three principal components.

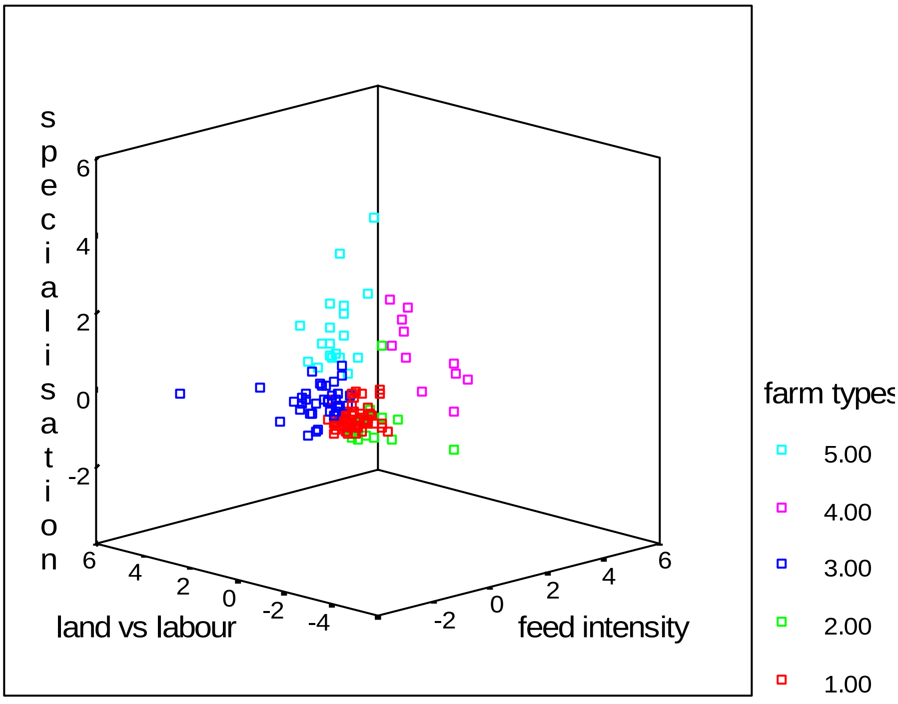


Figure 2a – 5-cluster solution with scores for "specialisation" by farm type

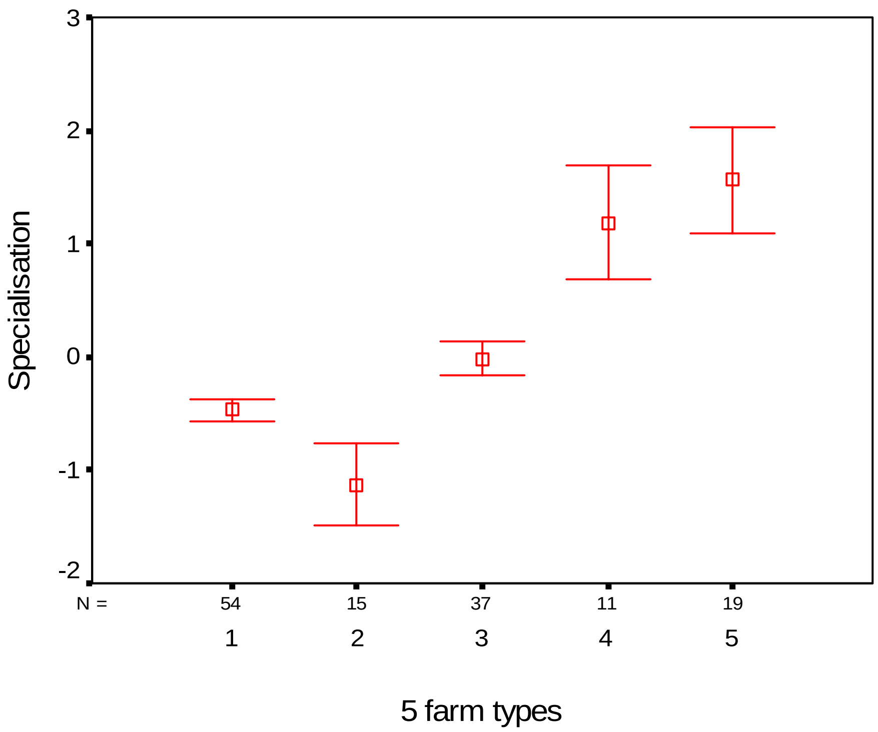


Figure 2b – 5-cluster solution with scores for "land vs labour" by farm type

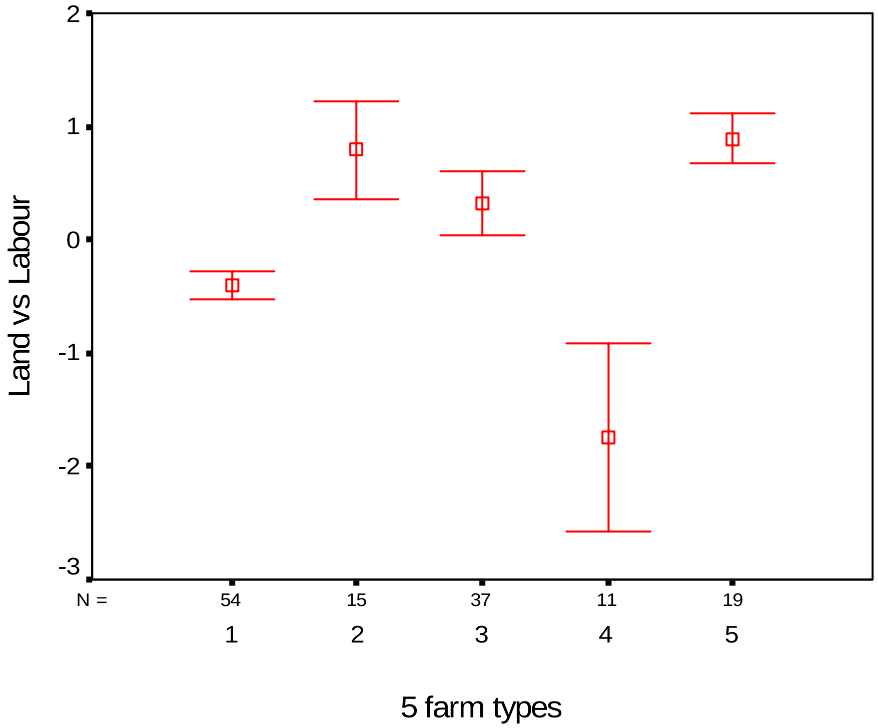


Figure 2c – 5-cluster solution with scores for "feed intensity" by farm type

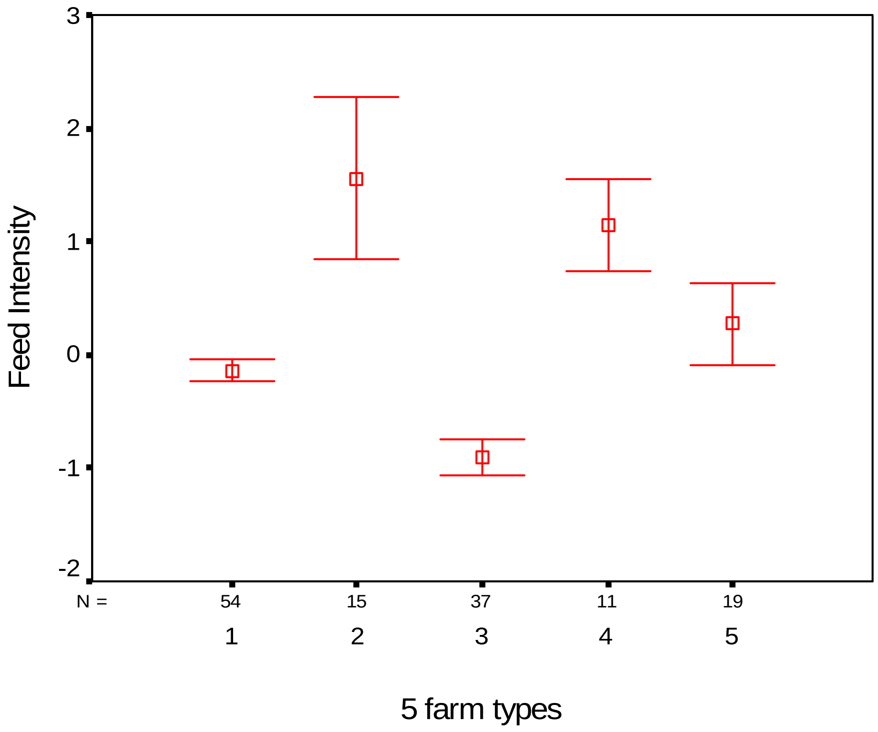


Table 7 – Details of a 5-cluster solution, giving rise to 5 farm types

		FARM SIZE (ha)	INORG FERT (kg/ha/yr)	ORGANIC FERT (kg/ha/yr)	TOTAL LABOUR (person days/ha/yr)	COMM. FEED (%)	PRAWN S.D. (fry/m^2)	MILKFISH S.D. (fry/m^2)	TOTAL FEEDS (kg/ha/yr)
1	N = 54								
	Mean	9.24	35.65	52.65	235.52	1.28	4.47	0.09	1908.55
	SE Mean	*1.09*	*11.71*	*24.24*	*20.20*	*0.77*	*0.45*	*0.01*	*308.14*
2	N = 15								
	Mean	2.88	31.40	0.00	370.41	6.71	**9.42**	0.18	**16248.34**
	SE Mean	*0.77*	*14.08*	*0.00*	*35.85*	*5.69*	*1.76*	*0.11*	*3429.52*
3	N = 37								
	Mean	3.97	189.33	214.80	**501.00**	8.44	1.20	0.16	559.96
	SE Mean	*0.85*	*35.55*	*69.33*	*65.28*	*4.05*	*0.36*	*0.02*	*270.91*
4	N = 11								
	Mean	**63.73**	136.03	**2750.48**	119.81	11.31	1.63	0.39	1251.60
	SE Mean	*13.66*	*40.39*	*713.00*	*38.84*	*9.14*	*0.82*	*0.12*	*705.15*
5	N = 19								
	Mean	6.13	**407.08**	**1113.36**	272.05	**76.93**	**0.00**	**0.71**	1858.59
	SE Mean	*1.46*	*115.60*	*379.81*	*35.28*	*8.53*	*0.00*	*0.12*	*872.66*
All	N = 136								
	Mean	11.08	137.00	457.35	318.37	15.20	3.27	0.23	3063.13
	SE Mean	*1.80*	*22.23*	*102.67*	*23.13*	*2.86*	*0.37*	*0.03*	*577.81*

5.5 Identifying the Farm Types

One-way Analysis of Variance (ANOVA) were carried out to determine statistically significant differences between the farm types. Important results from Scheffe's Post-Hoc tests are reported in the descriptions below, with full details given in appendix 6.

5.5.1 Type 1 – "Generalists" (n = 54, or 39.7% of sample)

Roughly neutral to all factors; Average size, no specialisation.

When carrying out a typology exercise, it is normal for a certain proportion of the sample to be average with regards to the variables of interest. By describing farms of this type as "Generalists", we observe that they show no degree of specialization in terms of production practices for either milkfish or prawn, and may therefore flexibly switch between these two species depending on supply of fry or market conditions.

Given that these are farms with no distinguishing features with regard to the dataset used in this exercise, it is possible that other variables are more important in identifying their characteristics. An example is the level of economic diversification on the farm between prawn, milkfish, crab and tilapia which are the four crops found to be cultured in our sample. Diversification of the farm between these crops has the benefit of spreading production risk and possible disease control via biological interactions between the crops.

Reporting the number of species cultured on the farm is one way of describing the diversity of the farm. However, this does not give information regarding the relative importance of each species to the revenue stream of the farm. Metzel and Ateng (1993), and Irz and Fatch (2004) use Simpson's Index to report crop diversity on farms in Bangladesh and Malawi respectively. Here we use the closely related Shannon Index, a more widely used index that has the attractive property of being bound between 0 (no diversification - the farm produces only one crop) and 1 (perfect diversification – the farm produces all possible crops, in our case 4, in equal proportions according to revenue).

The formula for the Shannon Index (H') is:

$$H' = -\Sigma\, p_i * \ln(p_i)$$

where p is the proportion of total revenue from species i.

$$H_{max} = \log(S)$$

where S is the number of species. Equitability (E), the measure reported here is given by H'/H_{max} and produces the index bound between 0 and 1 (Shaw, 2003, p.34).

From the results shown graphically in figure 3, we can observe that farm types 1 and 2 are economically diverse, whereas 3, 4 and 5 are less so. The differences between farms 1 and 2 in comparison with 3, 4 and 5 are statistically significant at the 5% level (see table 8 below).

Figure 3 – Revenue diversity indices by farm type

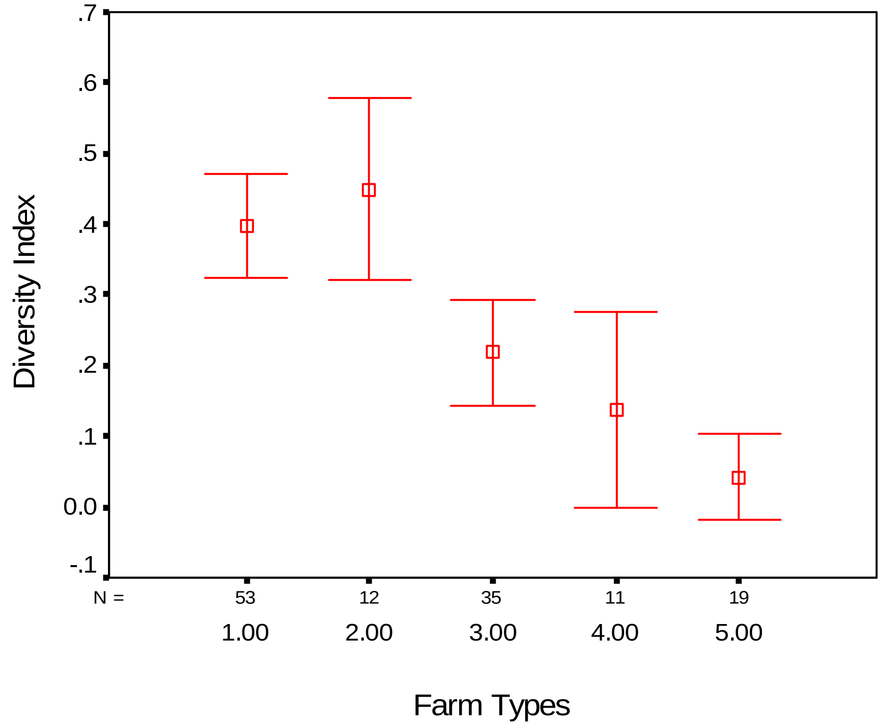


Table 8 – One-way ANOVA with Scheffe's Post-Hoc test for differences in mean diversity index between farm types

(I) Farm Type	(J) Farm Type	Mean Difference (I-J)	Std. Error	Sig.
1	2	-0.052	0.073	0.974
	3	0.179	0.050	0.015
	4	0.259	0.076	0.024
	5	0.355	0.061	0.000
2	1	0.052	0.073	0.974
	3	0.231	0.077	0.066
	4	0.311	0.096	0.037
	5	0.406	0.085	0.000

Therefore, we can conclude that "Generalist" is a good term to describe farm type 1, not just in terms of the production practices outlined in the typology, but when referenced to the level of economic diversification across possible crops.

5.5.2 Type 2 – “Prawn-Oriented Polyculture” (n = 15, or 11.0%)

Farms of this type have negative scores for factor 1, and are therefore oriented towards the production of prawns. Relative to the sample, labour is more important than land as a factor of production, as can be seen from small farm size and above-average labour intensity.

Farms of this type also have high total feeding rate, but with a low percentage of commercial feeds in the diet (6.7% by weight). From carrying out a one-way ANOVA, we can see that feeding rates are higher than those of all other farm types (significant at the 1% level) and that there are higher stocking densities of prawn fry on these farms than on all other farm types (significant at the 1% level). We therefore name this type as “Prawn-oriented polyculture”.

By referring to the results of the diversity index shown in figure 3, we can see that these farms, whilst oriented in their production towards prawns, actually are most successful in spreading their revenue most evenly across the candidate species for culture. This would suggest that the farmers attempt to ameliorate the risk associated with the prawns themselves, in the knowledge of how variable returns from prawn production can be. This means that while these farms are specialised in prawn production relative to the sample as a whole, they are not so in absolute terms (i.e. they are not prawn monoculture systems).

5.5.3 Type 3 – “Low Input, Labour Intensive Farms” (n = 37, or 27.2%)

Farms of this type are neutral to factor 1, and are therefore not specialized with respect to either prawn or milkfish production. They have positive scores for factor 2 and so labour is much more important as a factor of production than land. From the results of a one-way ANOVA, we observe that these farms have higher labour use than farm types 1 and 4 (significant at the 1% level) and farm type 5 (significant at the 5% level). They have negative scores for factor 3 and are very feed-extensive. They have lower feed-intensities than all other farm types.

The amount of fertiliser used in these systems is moderate and low stocking densities are used. These really are very extensive farms and there could be interesting issues to do with access to credit for poor fish farmers for these systems. Alternatively, it may be that these farms are under-utilised because the motivations of the operator do not relate to maximising levels of production or profit but to some other objective (e.g. to have control of land in the area; for leisure as a break from another activity). These are hypotheses that can be explored.

5.5.4 Type 4 – "Large, Milkfish-Oriented Systems" (n = 11, or 8.1%)

Farms of this type are positive for factor 1 and are therefore specialized in milkfish production. They have negative scores for factor 2 and therefore land is more important than labour as a factor of production. Feeding rates are approximately average for the sample.

From the results of a one-way ANOVA, we observe that these farms are larger in size than farms belonging to all other farm types (significant at the 1% level). It is their size that defines them primarily, but there is a tendency for milkfish-orientation on these farms. Large ponds, fertilized with large amounts of manure are used on this farm type. Labour intensity is lower than for any other farm type and stocking densities are low.

These farms tend to be operated by local elites and the income from the fish farms, despite their size, is unlikely to be the main one for the operator. As mentioned previously, the motivation for entering fish farming may not be production-related and control of the land may be important for local political objectives held by the operator. There are a number of social issues relating to these farm types, notably the potential for land reform.

5.5.5 Type 5 – "Small Milkfish Monoculture Farms" (n = 19, or 14.0%)

Positive scores for factor 1 suggest that these farms are milkfish-specialised. They are positive for factor 2 and therefore labour is more important than land as a factor of production. From the results of a number of one-way ANOVA test, we find that these farms have higher use of commercial feeds than all other farm types (significant at the 1%); have higher stocking densities of milkfish fry than all other farm types (significant at the 5% level); and have higher use of inorganic fertilizers than all other farm types (significant at at least the 5% level).

No other species are stocked in these systems and therefore they are entirely dependent on milkfish for their income. There has been a large increase in the production of milkfish from non-pond aquaculture (e.g. pens, cages) recently in the Philippines and so these systems are suffering from lower prices and their margins are being squeezed. It will be interesting to follow whether diversification into the other candidate species will follow (along the lines of the "Generalist" farm type) or whether these operators, whose production practices are entirely set up for milkfish culture, will try and stick it out in the hope of an increase again in the market price.

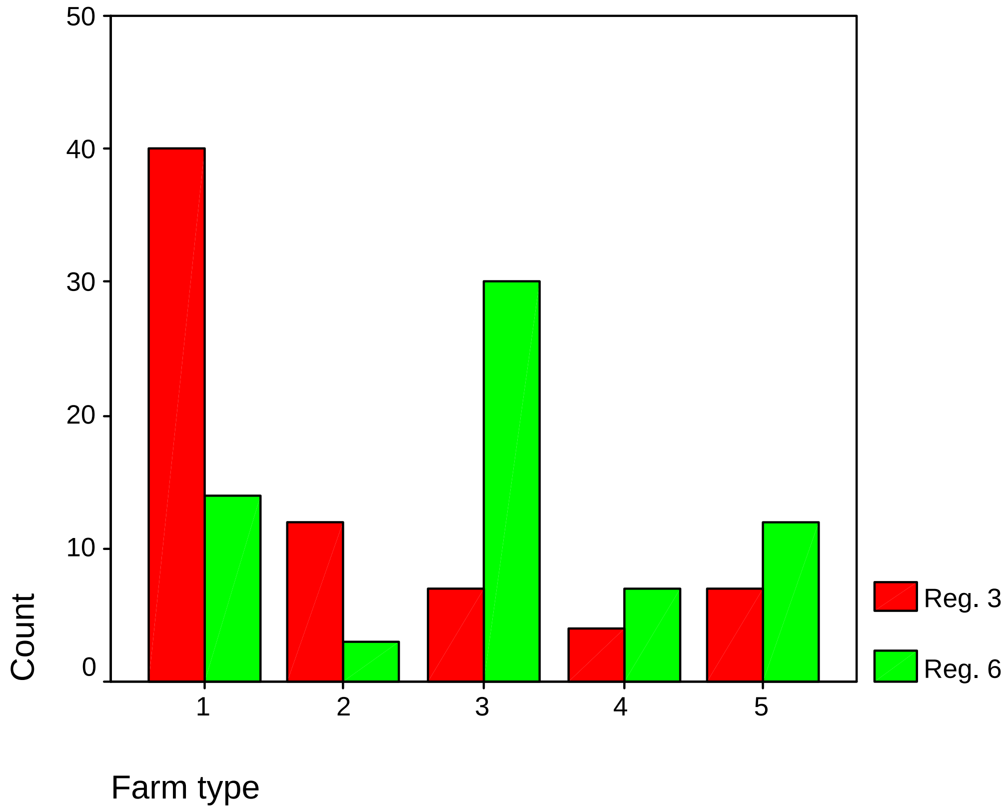
6 Geographic Distribution

We can observe that there is a geographically biased distribution for farm types in our sample. As previously outlined in section 4.1, sampling effort was split almost equally between two regions – 49% in Central Luzon (region 3) and 51% in Western Visayas (region 6). As table 9 and figure 4 show below, most prawn-oriented farms are found in region 3 (80%). Generalists are also somewhat concentrated in region 3 (74%). On the other hand, low-input high-labour systems are particularly strongly concentrated in region 6.

Table 9 – Values for regional dummy variables

Farm Type	% in Region 6
1 – Generalist	0.26
2 – Prawn-oriented polyculture	0.20
3 – Low input systems, labour intensive	0.81
4 – Large, milkfish oriented-systems	0.64
5 – Small milkfish monoculture farms	0.63
Total sample (all farm types)	0.49

Figure 4 – Geographic distribution by farm type



7 Conclusion

The results of the principal components analysis are easily interpreted and are in line with expectations held *ex-ante* with regard to possible latent variable structure. One possible cluster solution containing five farm types has been outlined and their defining characteristics highlighted.

What we have effectively generated with this analysis is a survey of the current farming systems in the Philippines. While this is useful as an end in itself, we see it primarily as a means to aid comparative study in policy. For instance, in the case of a single objective (such as increase food security), we can then study protein budgets for each of the clusters to identify the 'best' production system for this objective. However, we believe that policy regarding sustainable development of the aquaculture sector requires a multiple-criteria approach to appraisal, as the following two quotes should help illustrate:

> *"The super-intensive cage farms are inefficient in nutrient and labour use….but provide very high returns to land and capital investment. Clearly there are trade-offs between the use efficiencies of different resources, and local demand for these resources has implications for the relative merits of alternative systems."* Michielsens *et al* (2002, p. 412).

> *"The extensive farming method finds its validity but also its limits in its link with natural productivity. It is characterized by a favourable energy balance, but by rather low production per surface unit."* Ravagnan (1981, p.66)

In complex cases where there are a number of competing objectives (e.g. maximize economic performance, minimize ecological impact, maximize social equity) then we can explore the trade-offs at the farm-level between ecological, social and economic properties of the farming systems. In addition, we can examine the determinants of geographical biases in the adoption of particular farming systems. These topics will be the subject of subsequent working papers under this project.

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Appendix 1a – *Stratification of a net sample size of 70 farms for region 3*

Total Farms in Sample	**Bataan**	**Bulacan**	**Pampanga**	**Zambales**
# Farms > 10 ha	**2** (2)	**4** (4)	**9** (8)	**0** (1)
# Farms 2 – 10 ha	**6** (5)	**7** (7)	**21** (19)	**0** (3)
# Farms < 2 ha	**3** (3)	**5** (3)	**11** (10)	**2** (4)
Total	**11** (10)	**16** (14)	**41** (38)	**2** (8)

The table above shows the stratification of the net sample of 70 farms in region 3. The figures in bold represent the stratification of the actual net sample collected during fieldwork. The figures in parentheses represent the number that would be completely representative of the region, according to the Bureau of Agricultural Statistics (BAS) inventory from 1997. Zambales is deliberately under-represented because, in carrying out work in that province it was found that most of the farms were actually only nursery systems ("kawagan") that supply fingerlings to the grow-out systems in Bataan, Bulacan and Pampanga. They are not directly comparable in our analysis as they are not aquaculture grow-out systems and so have been omitted from the net sample.

Appendix 1b - *Stratification of a net sample size of 67 farms for region 6*

Total Farms in Sample	**Aklan**	**Antique**	**Capiz**	**Guimaras**	**Iloilo**	**Negros Occ.**
# Farms > 10 ha	**2** (2)	**0** (0)	**5** (5)	**0** (0)	**5** (5)	**7** (3)
# Farms 2 - 10 ha	**8** (7)	**0** (1)	**10** (10)	**0** (1)	**4** (5)	**7** (8)
# Farms < 2 ha	**7** (7)	**0** (1)	**3** (5)	**0** (1)	**4** (4)	**5** (4)
Total	**17** (16)	**0** (2)	**18** (19)	**0** (2)	**13** (14)	**19** (16)

The table above shows the stratification of the net sample of 67 farms in region 6. Antique and Guimaras provinces have limited suitable area for fishponds and are only marginal in the regional production, so were not included in the fieldwork. As before, the figures in bold represent the stratification of the actual net sample collected during fieldwork. The figures in parentheses represent the number that would be completely representative of the region, according to the BAS inventory from 1997.

Appendix 2 – *Correlation matrix for the 8 variables*

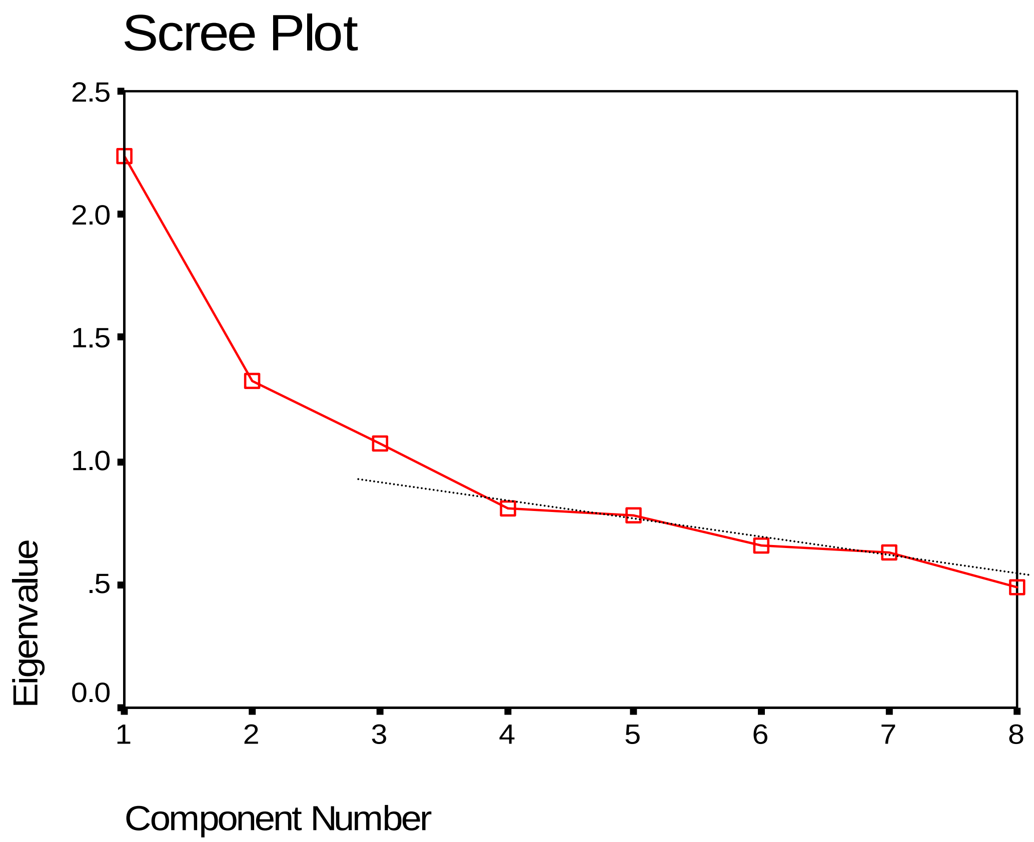
a) Correlation Matrix

	FARMSIZE	INORG	ORGANIC	TOTAL LABOUR	SUGPO S.D.	BANGUS S.D.	TOTAL FEEDS	COMM. FEED
FARMSIZE	1.000	.001	.182	-.248	-.102	.054	-.120	-.018
INORG	.001	1.000	.330	-.015	-.292	.245	-.138	.241
ORGANIC	.182	.330	1.000	-.166	-.233	.363	-.134	.245
TOTLABOR	-.248	-.015	-.166	1.000	.031	.027	.106	-.031
SUGPOSD	-.102	-.292	-.233	.031	1.000	-.295	.312	-.196
BANGUSSD	.054	.245	.363	.027	-.295	1.000	.025	.360
TOTFEEDS	-.120	-.138	-.134	.106	.312	.025	1.000	-.074
COMMFEED	-.018	.241	.245	-.031	-.196	.360	-.074	1.000

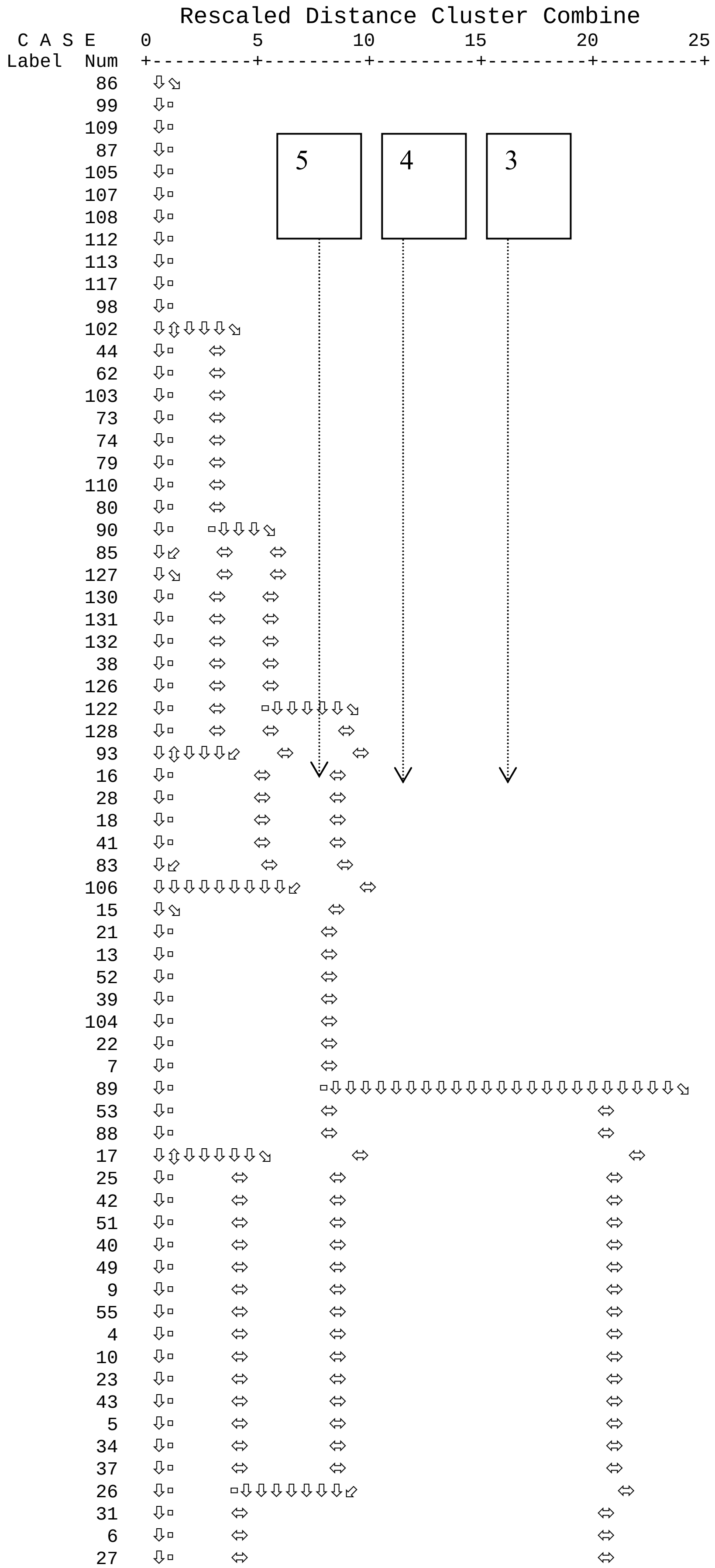
b) Significance of correlations

	FARMSIZE	INORG	ORGANIC	TOTAL LABOUR	SUGPO S.D.	BANGUS S.D.	TOTAL FEEDS	COMM. FEED
FARMSIZE		.497	.017	.002	.118	.267	.081	.417
INORG	.497		.000	.432	.000	.002	.054	.002
ORGANIC	.017	.000		.026	.003	.000	.060	.002
TOTLABOR	.002	.432	.026		.360	.379	.109	.361
SUGPOSD	.118	.000	.003	.360		.000	.000	.011
BANGUSSD	.267	.002	.000	.379	.000		.385	.000
TOTFEEDS	.081	.054	.060	.109	.000	.385		.198
COMMFEED	.417	.002	.002	.361	.011	.000	.198	

Appendix 3 – *Scree Plot showing extraction of principal components*



Appendix 4 – *Dendrogram of Cluster Analysis output*



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  8   ⇩⇙    ⇔                        ⇔
 14   ⇩⇘    ⇔                        ⇔
134   ⇩▫    ⇔                       ⇔
  3   ⇩▫    ⇔                       ⇔
  1   ⇩▫    ⇔                       ⇔
 30   ⇩▫    ⇔                       ⇔
 63   ⇩⇧⇩⇘   ⇔                       ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘
  2   ⇩▫ ⇔  ⇔                        ⇔       ⇔
 54   ⇩▫ ⇔  ⇔                        ⇔       ⇔
 57   ⇩▫ ⇔  ⇔                        ⇔       ⇔
 33   ⇩▫ ⇔  ⇔                        ⇔       ⇔
 97   ⇩▫ ⇔  ⇔                        ⇔       ⇔
135   ⇩⇙ ▫⇩⇩⇩⇙                       ⇔       ⇔
 68   ⇩⇘ ⇔                           ⇔       ⇔
118   ⇩▫ ⇔                          ⇔       ⇔
 29   ⇩▫ ⇔                          ⇔       ⇔
114   ⇩▫ ⇔                          ⇔       ⇔
101   ⇩▫ ⇔                          ⇔       ⇔
124   ⇩▫ ⇔                          ⇔       ⇔
 92   ⇩⇧⇩⇙                           ⇔       ⇔
 96   ⇩▫                            ⇔       ⇔
115   ⇩▫                            ⇔       ⇔
116   ⇩▫                            ⇔       ⇔
 75   ⇩⇙                            ⇔       ⇔
 48   ⇩⇘                            ⇔       ⇔
 56   ⇩▫                            ⇔       ⇔
 32   ⇩▫                            ⇔       ⇔
 11   ⇩⇧⇩⇩⇩⇘                         ⇔       ⇔
 36   ⇩▫  ⇔                         ⇔       ⇔
 19   ⇩▫  ⇔                         ⇔       ⇔
 35   ⇩▫  ⇔                         ⇔       ⇔
 58   ⇩▫  ▫⇩⇩⇩⇩⇩⇩⇩⇘                  ⇔        ⇔
 84   ⇩⇙   ⇔     ⇔                   ⇔       ⇔
 12   ⇩⇘   ⇔     ⇔                   ⇔       ⇔
111   ⇩▫  ⇔     ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙       ⇔
 20   ⇩▫  ⇔      ⇔                          ⇔
 77   ⇩⇧⇩⇩⇩⇙      ⇔                          ⇔
 47   ⇩⇙         ⇔                          ⇔
 24   ⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙                           ⇔
 61   ⇩×⇩⇩⇩⇩⇩⇘                               ⇔
 72   ⇩⇙    ⇔                               ⇔
 81   ⇩⇘    ⇔                               ⇔
 94   ⇩▫    ⇔                               ⇔
 69   ⇩▫    ⇔                               ⇔
 59   ⇩▫   ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇘               ⇔
125   ⇩▫    ⇔                ⇔              ⇔
 70   ⇩⇧⇩⇘   ⇔                ⇔              ⇔
 64   ⇩▫ ⇔  ⇔                ⇔               ⇔
 71   ⇩▫ ⇔  ⇔                ⇔               ⇔
 82   ⇩⇙ ⇔   ⇔                ⇔              ⇔
 65   ⇩⇘ ▫⇩⇩⇩⇙               ⇔               ⇔
 67   ⇩▫ ⇔                   ⇔              ⇔
 95   ⇩▫ ⇔                   ⇔              ⇔
 46   ⇩▫ ⇔                  ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙
 60   ⇩⇧⇩⇙                   ⇔
 66   ⇩▫                    ⇔
129   ⇩▫                    ⇔
123   ⇩⇙                     ⇔
 78   ⇩⇘                     ⇔
119   ⇩⇧⇩⇩⇩⇩⇩⇩⇩⇩⇘              ⇔
121   ⇩▫     ⇔               ⇔
133   ⇩⇙      ⇔              ⇔
 50   ⇩⇘     ▫⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇩⇙
 76   ⇩▫     ⇔
 91   ⇩▫     ⇔
100   ⇩⇧⇩⇩⇩⇩⇩⇩⇩⇙
120   ⇩▫
 45   ⇩▫
136   ⇩⇙
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Appendix 5 – *Analysis of variance (ANOVA)of the differences in mean factor scores for five farm types using Scheffe's Post-Hoc Test*

Dependent Variable	Grouping Variables (I) Farm Type	(J) Farm Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Factor 1 - Specialism	1	2	0.656	0.165	0.005*	0.140	1.172
		3	-0.457	0.121	0.008*	-0.834	-0.079
		4	-1.658	0.187	0.000*	-2.243	-1.073
		5	-2.035	0.151	0.000*	-2.507	-1.563
	2	1	-0.656	0.165	0.005*	-1.172	-0.140
		3	-1.113	0.173	0.000*	-1.654	-0.571
		4	-2.314	0.225	0.000*	-3.016	-1.612
		5	-2.691	0.196	0.000*	-3.302	-2.080
	3	1	0.457	0.121	0.008*	0.079	0.834
		2	1.113	0.173	0.000*	0.571	1.654
		4	-1.201	0.194	0.000*	-1.809	-0.594
		5	-1.578	0.160	0.000*	-2.077	-1.079
	4	1	1.658	0.187	0.000*	1.073	2.243
		2	2.314	0.225	0.000*	1.612	3.016
		3	1.201	0.194	0.000*	0.594	1.809
		5	-0.377	0.214	0.545	-1.047	0.293
	5	1	2.035	0.151	0.000*	1.563	2.507
		2	2.691	0.196	0.000*	2.080	3.302
		3	1.578	0.160	0.000*	1.079	2.077
		4	0.377	0.214	0.545	-0.293	1.047
Factor 2 - Land vs Labour	1	2	-1.191	0.204	0.000*	-1.830	-0.552
		3	-0.726	0.149	0.000*	-1.193	-0.259
		4	1.346	0.232	0.000*	0.623	2.070
		5	-1.296	0.187	0.000*	-1.880	-0.713
	2	1	1.191	0.204	0.000*	0.552	1.830
		3	0.465	0.214	0.324	-0.205	1.135
		4	2.537	0.278	0.000*	1.669	3.406
		5	-0.105	0.242	0.996	-0.861	0.650
	3	1	0.726	0.149	0.000*	0.259	1.193
		2	-0.465	0.214	0.324	-1.135	0.205
		4	2.072	0.240	0.000*	1.321	2.824
		5	-0.570	0.198	0.087***	-1.188	0.047
	4	1	-1.346	0.232	0.000*	-2.070	-0.623
		2	-2.537	0.278	0.000*	-3.406	-1.669
		3	-2.072	0.240	0.000*	-2.824	-1.321
		5	-2.643	0.265	0.000*	-3.472	-1.814
	5	1	1.296	0.187	0.000*	0.713	1.880
		2	0.105	0.242	0.996	-0.650	0.861
		3	0.570	0.198	0.087***	-0.047	1.188
		4	2.643	0.265	0.000*	1.814	3.472

Dependent Variable	(I)	(J)	Difference (I-J)	Std. Error	Sig.	95% C.I. Lower Bound	95% C.I. Upper Bound
Factor 3 - Feed Intensity	1	2	-1.696	0.183	0.000*	-2.269	-1.123
		3	0.760	0.134	0.000*	0.341	1.178
		4	-1.290	0.208	0.000*	-1.940	-0.641
		5	-0.413	0.168	0.200	-0.937	0.110
	2	1	1.696	0.183	0.000*	1.123	2.269
		3	2.456	0.192	0.000*	1.855	3.057
		4	0.406	0.249	0.619	-0.373	1.185
		5	1.283	0.217	0.000*	0.605	1.961
	3	1	-0.760	0.134	0.000*	-1.178	-0.341
		2	-2.456	0.192	0.000*	-3.057	-1.855
		4	-2.050	0.216	0.000*	-2.724	-1.376
		5	-1.173	0.177	0.000*	-1.727	-0.619
	4	1	1.290	0.208	0.000*	0.641	1.940
		2	-0.406	0.249	0.619	-1.185	0.373
		3	2.050	0.216	0.000*	1.376	2.724
		5	0.877	0.238	0.011**	0.133	1.621
	5	1	0.413	0.168	0.200	-0.110	0.937
		2	-1.283	0.217	0.000*	-1.961	-0.605
		3	1.173	0.177	0.000*	0.619	1.727
		4	-0.877	0.238	0.011**	-1.621	-0.133

where (*) denotes significant at the 1% level

where (**) denotes significant at the 5% level

where (***) denotes significant at the 10% level

Appendix 6 - *Analysis of variance (ANOVA) of the differences in mean values for the original set of 8 variables for five farm types using Scheffe's Post-Hoc Test*

						95% Confidence Interval	
	(I) Farm Type	(J) Farm Type	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
FARMSIZE	1	2	6.366	4.094	0.660	-6.425	19.157
		3	5.271	2.993	0.543	-4.082	14.625
		4	-54.485	4.640	0.000	-68.982	-39.987
		5	3.116	3.741	0.952	-8.574	14.806
	2	1	-6.366	4.094	0.660	-19.157	6.425
		3	-1.095	4.293	0.999	-14.509	12.320
		4	-60.851	5.568	0.000	-78.248	-43.453
		5	-3.250	4.845	0.978	-18.387	11.888
	3	1	-5.271	2.993	0.543	-14.625	4.082
		2	1.095	4.293	0.999	-12.320	14.509
		4	-59.756	4.817	0.000	-74.807	-44.705
		5	-2.155	3.959	0.990	-14.525	10.214
	4	1	54.485	4.640	0.000	39.987	68.982
		2	60.851	5.568	0.000	43.453	78.248
		3	59.756	4.817	0.000	44.705	74.807
		5	57.601	5.314	0.000	40.997	74.205
	5	1	-3.116	3.741	0.952	-14.806	8.574
		2	3.250	4.845	0.978	-11.888	18.387
		3	2.155	3.959	0.990	-10.214	14.525
		4	-57.601	5.314	0.000	-74.205	-40.997
INORG	1	2	4.248	66.822	1.000	-204.545	213.041
		3	-153.676	48.861	0.048	-306.347	-1.005
		4	-100.380	75.736	0.780	-337.024	136.265
		5	-371.430	61.069	0.000	-562.249	-180.612
	2	1	-4.248	66.822	1.000	-213.041	204.545
		3	-157.924	70.080	0.285	-376.896	61.048
		4	-104.628	90.883	0.856	-388.601	179.346
		5	-375.678	79.078	0.000	-622.766	-128.591
	3	1	153.676	48.861	0.048	1.005	306.347
		2	157.924	70.080	0.285	-61.048	376.896
		4	53.296	78.625	0.977	-192.377	298.969
		5	-217.755	64.618	0.027	-419.661	-15.848
	4	1	100.380	75.736	0.780	-136.265	337.024
		2	104.628	90.883	0.856	-179.346	388.601
		3	-53.296	78.625	0.977	-298.969	192.377
		5	-271.051	86.741	0.050	-542.083	-0.019
	5	1	371.430	61.069	0.000	180.612	562.249
		2	375.678	79.078	0.000	128.591	622.766
		3	217.755	64.618	0.027	15.848	419.661
		4	271.051	86.741	0.050	0.019	542.083
ORGANIC	1	2	52.650	271.480	1.000	-795.624	900.923
		3	-162.153	198.509	0.955	-782.417	458.111
		4	-2697.827	307.695	0.000	-3659.256	-1736.398
		5	-1060.715	248.110	0.002	-1835.964	-285.465
	2	1	-52.650	271.480	1.000	-900.923	795.624

		3	-214.802	284.716	0.966	-1104.431	674.827
		4	-2750.477	369.234	0.000	-3904.191	-1596.762
		5	-1113.364	321.273	0.021	-2117.219	-109.510
	3	1	162.153	198.509	0.955	-458.111	782.417
		2	214.802	284.716	0.966	-674.827	1104.431
		4	-2535.674	319.433	0.000	-3533.781	-1537.567
		5	-898.562	262.526	0.023	-1718.857	-78.267
	4	1	2697.827	307.695	0.000	1736.398	3659.256
		2	2750.477	369.234	0.000	1596.762	3904.191
		3	2535.674	319.433	0.000	1537.567	3533.781
		5	1637.112	352.407	0.000	535.976	2738.249
	5	1	1060.715	248.110	0.002	285.465	1835.964
		2	1113.364	321.273	0.021	109.510	2117.219
		3	898.562	262.526	0.023	78.267	1718.857
		4	-1637.112	352.407	0.000	-2738.249	-535.976
TOTLABOR	1	2	-134.881	70.787	0.462	-356.063	86.301
		3	-265.478	51.760	0.000	-427.208	-103.748
		4	115.713	80.230	0.721	-134.974	366.400
		5	-36.528	64.693	0.988	-238.670	165.614
	2	1	134.881	70.787	0.462	-86.301	356.063
		3	-130.597	74.238	0.544	-362.563	101.368
		4	250.594	96.275	0.155	-50.230	551.418
		5	98.353	83.770	0.847	-163.396	360.102
	3	1	265.478	51.760	0.000	103.748	427.208
		2	130.597	74.238	0.544	-101.368	362.563
		4	381.191	83.290	0.001	120.941	641.442
		5	228.950	68.452	0.029	15.063	442.837
	4	1	-115.713	80.230	0.721	-366.400	134.974
		2	-250.594	96.275	0.155	-551.418	50.230
		3	-381.191	83.290	0.001	-641.442	-120.941
		5	-152.241	91.888	0.603	-439.356	134.874
	5	1	36.528	64.693	0.988	-165.614	238.670
		2	-98.353	83.770	0.847	-360.102	163.396
		3	-228.950	68.452	0.029	-442.837	-15.063
		4	152.241	91.888	0.603	-134.874	439.356
COMMFEED	1	2	-5.431	6.469	0.950	-25.644	14.781
		3	-7.160	4.730	0.683	-21.939	7.620
		4	-10.033	7.332	0.759	-32.941	12.876
		5	-75.651	5.912	0.000	-94.123	-57.179
	2	1	5.431	6.469	0.950	-14.781	25.644
		3	-1.728	6.784	0.999	-22.926	19.469
		4	-4.601	8.798	0.991	-32.092	22.889
		5	-70.220	7.655	0.000	-94.139	-46.300
	3	1	7.160	4.730	0.683	-7.620	21.939
		2	1.728	6.784	0.999	-19.469	22.926
		4	-2.873	7.611	0.998	-26.656	20.909
		5	-68.491	6.255	0.000	-88.037	-48.946
	4	1	10.033	7.332	0.759	-12.876	32.941
		2	4.601	8.798	0.991	-22.889	32.092
		3	2.873	7.611	0.998	-20.909	26.656
		5	-65.618	8.397	0.000	-91.855	-39.381
	5	1	75.651	5.912	0.000	57.179	94.123

		2	70.220	7.655	0.000	46.300	94.139
		3	68.491	6.255	0.000	48.946	88.037
		4	65.618	8.397	0.000	39.381	91.855
SUGPOSD	1	2	-4.946	0.976	0.000	-7.997	-1.895
		3	3.270	0.714	0.001	1.039	5.501
		4	2.838	1.107	0.167	-0.619	6.296
		5	4.471	0.892	0.000	1.683	7.259
	2	1	4.946	0.976	0.000	1.895	7.997
		3	8.216	1.024	0.000	5.017	11.416
		4	7.785	1.328	0.000	3.635	11.934
		5	9.417	1.155	0.000	5.807	13.028
	3	1	-3.270	0.714	0.001	-5.501	-1.039
		2	-8.216	1.024	0.000	-11.416	-5.017
		4	-0.431	1.149	0.998	-4.021	3.158
		5	1.201	0.944	0.805	-1.749	4.151
	4	1	-2.838	1.107	0.167	-6.296	0.619
		2	-7.785	1.328	0.000	-11.934	-3.635
		3	0.431	1.149	0.998	-3.158	4.021
		5	1.633	1.267	0.798	-2.328	5.593
	5	1	-4.471	0.892	0.000	-7.259	-1.683
		2	-9.417	1.155	0.000	-13.028	-5.807
		3	-1.201	0.944	0.805	-4.151	1.749
		4	-1.633	1.267	0.798	-5.593	2.328
BANGUSSD	1	2	-0.092	0.080	0.862	-0.343	0.160
		3	-0.075	0.059	0.805	-0.259	0.109
		4	-0.296	0.091	0.038	-0.581	-0.011
		5	-0.622	0.074	0.000	-0.851	-0.392
	2	1	0.092	0.080	0.862	-0.160	0.343
		3	0.017	0.084	1.000	-0.247	0.280
		4	-0.204	0.109	0.484	-0.546	0.138
		5	-0.530	0.095	0.000	-0.828	-0.233
	3	1	0.075	0.059	0.805	-0.109	0.259
		2	-0.017	0.084	1.000	-0.280	0.247
		4	-0.221	0.095	0.252	-0.517	0.075
		5	-0.547	0.078	0.000	-0.790	-0.304
	4	1	0.296	0.091	0.038	0.011	0.581
		2	0.204	0.109	0.484	-0.138	0.546
		3	0.221	0.095	0.252	-0.075	0.517
		5	-0.326	0.104	0.050	-0.652	0.000
	5	1	0.622	0.074	0.000	0.392	0.851
		2	0.530	0.095	0.000	0.233	0.828
		3	0.547	0.078	0.000	0.304	0.790
		4	0.326	0.104	0.050	0.000	0.652
TOTFEEDS	1	2	-14339.789	1432.247	0.000	-18815.02	-9864.563
		3	1348.594	1047.270	0.798	-1923.727	4620.915
		4	656.947	1623.302	0.997	-4415.253	5729.148
		5	49.955	1308.951	1.000	-4040.021	4139.930
	2	1	14339.789	1432.247	0.000	9864.563	18815.015
		3	15688.383	1502.073	0.000	10994.977	20381.789
		4	14996.736	1947.962	0.000	8910.096	21083.376
		5	14389.743	1694.934	0.000	9093.719	19685.768
	3	1	-1348.594	1047.270	0.798	-4620.915	1923.727

		2	-15688.383	1502.073	0.000	-20381.79	-10994.977
		4	-691.647	1685.230	0.997	-5957.350	4574.056
		5	-1298.640	1385.008	0.927	-5626.262	3028.982
	4	1	-656.947	1623.302	0.997	-5729.148	4415.253
		2	-14996.736	1947.962	0.000	-21083.38	-8910.096
		3	691.647	1685.230	0.997	-4574.056	5957.350
		5	-606.993	1859.188	0.999	-6416.248	5202.262
	5	1	-49.955	1308.951	1.000	-4139.930	4040.021
		2	-14389.743	1694.934	0.000	-19685.77	-9093.719
		3	1298.640	1385.008	0.927	-3028.982	5626.262
		4	606.993	1859.188	0.999	-5202.262	6416.248