國立臺灣海洋大學

水產養殖學系

碩士學位論文

指導教授：繆峽 博士

台灣吳郭魚養殖業發展之經濟效評估

Economic Evaluation of Tilapia Grow-out Farming in Taiwan

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中華民國 104 年 6 月

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水 產 養 殖 學 系

碩 士 論 文

A Thesis
Submitted to Department of Aquaculture
College of Life Sciences
National Taiwan Ocean University
In Partial Fulfillment of the Requirements
For the Degree of
Master of Science
In
Aquaculture

June 2015
Keelung, Taiwan, Republic of China

中華民國104年 6月

國立臺灣海洋大學水產養殖學系

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之碩士學位論文

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中華民國 104 年 6 月 4 日

ACKNOWLEDGEMENTS

My thanks go to anyone who contributed in one way or another to make this study possible. Thus, I express my deep gratitude to:

- Almighty "God" for giving me ability and protection until today;
- Dr. Sha Miao, my scientific advisor, to have carefully guided me through his pertinent remarks and advices which helped me to carry out this research;
- International Cooperation Development Fund (TaiwanICDF) for financially supporting my study in Taiwan;
- My parents, Nicolas Charles and Maricile Destiné Charles, for their guidance and efforts, otherwise I would not be here today;
- Haitian Government through the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR) that had selected me for this scholarship;
- Teaching staff of NTOU, especially those from Aquaculture Department;
- OIA's members for their support and help;
- Eileen Chen, our program manager, for her support;
- Anne Daphkar Pacius, my fiancée, for her moral and affective supports during my study;
- My brothers, Roland, Amiaud, Jean-Gardy and Barthélémy Charles, for their encouragement;
- Ling Ling Goh Emmy for translating the Chinese data into English for me and Randy Morton for his help;
- My lab mates and classmates especially Shu-Fen, and Nick Liu for their assistance;
- My country mate, Agr. Amos Vanté and one of my best friends, Agr. Edvard Joseph, for their respective supports;
- All those who their name is not mentioned here, but who have made possible this work.

CHINESE ABSTRACT

本研究透過生產規模大小與地理位置之區隔差異，使用多變量統計分析針對2008**年臺灣**吳郭魚養殖產業進行經濟評估。生物性變數包含放養密度與活存率，經濟性變數包含成本投入密度及獲利能力。透過Cobb-Douglas**生**產函數分析結果表明，其成本投入密度會隨生產規模與地理位置之差異而達到顯著影響。因此，發現臺灣南部大規模飼養的吳郭魚養殖場更具有經濟效益。典型相關分析表明，生物性變數與經濟性變數為高度顯著相關。最後，Cobb-Douglas**生**產函數顯示產業不具有經濟規模效應。

關鍵字:經濟評估、臺灣、生產規模、地理位置與規模不經**濟**

ENGLISH ABSTRACT

This study aimed to make an economic evaluation of tilapia grow-out farming in Taiwan during the year 2008. Two sets of variables were considered for this study. The first set consisted of biological variables, which included stocking density and survival rate, and the second set were economic variables comprised of the input intensities and varied profitabilities. It was concluded that the interaction of production scale and geographical location had significant effects on input intensity variables; however, only the geographical location and its interaction with production scale had a significant effect on the varied profitability variables. In addition, tilapia grow-out farms that operate under large scale in southern Taiwan were found to be more economically efficient. The canonical correlation indicated that biological and economic variables were significantly correlated. Finally, the Cobb-Douglas production function revealed that there were diseconomies of scale.

Key words: Economic evaluation, Taiwan, Production scale, Geographical location and Diseconomies of scale.

LIST OF ABBREVIATION INITIALS

ANOVA	Analysis of Variance
ASC	Aquaculture Stewardship Council
B.C.	Before Christ
CCA	Discriminant Function Analysis
DO	Dissolved Oxygen
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FC	Fixed Cost
FF	Feed-Fertilizer
Fig	Figure
FR	Fry
FTA	Free Trade Agreement
G	Gram
GIO	Government Information Office
Ha	Hectare
ICDF	International Cooperation Development Fund
Kg	Kilogram
LR	Labor
MANOVA	Multivariate of Analysis of Variance
MR	Maintenance-Repair
MT	Metric Ton
NMFS	National Marine Fisheries Services
NR	Net Return
NTD	New Taiwan Dollar

NTOU	National Taiwan Ocean University
^{o}C	Degree Celsius
^{o}F	Degree Fahrenheit
OIA	Office of International Affairs
PCA	Principal Component Analysis
PPT	Unit Parts Per Thousand
ROC	Republic of China
T2A	Taiwan Tilapia Alliance
UAE	United Arab Emirates
USA	United States of America
USD	United States Dollar
WEF	Water Electricity Fuel

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I. INTRODUCTION

1.1 Research Problem

Aquaculture economics deals with raising of desirable aquatic animals or plants under controlled or semi-controlled conditions for economic or social advantages in order to satisfy some human needs. The allocation and utilization of limited resources: land, labor, capital and management remain the main challenge in the production of aquatic organisms (FAO, Glossary of Aquaculture). In addition to its important role in employment creation, income generation and food security improvement, the trade in fish represents a significant source of foreign currency earnings (FAO, 2010).

From 1950 to 2010, the global aquaculture production increased rapidly with the exception of 1980s and 1990s where it was slower (Fig.1) (FAO, 2012). In 2012, world aquaculture production reached another high peak at 90.4 million tonnes (live weight equivalent) (US$144.4 billion), including 66.6 million tonnes of food fish (US$137.7 billion) and 23.8 million tonnes of aquatic algae (mostly seaweeds, US$6.4 billion). Additionally, some countries also reported collectively 22,400 tonnes of non-food products (US$222.4 million). From 1980 to 2012, world aquaculture production volume increased at an average rate of 8.6% per year. World food fish aquaculture production more than doubled from 32.4 million tonnes to 66.6 million tonnes in 2000 and 2012, respectively (FAO, 2014).

In consideration of economic status of countries and their geographical localization the global distribution of aquaculture production remains imbalanced. In 2010 the top ten producing countries accounted for 87.6 percent in volume and 81.9% in value of the world's farmed food fish. However, Asia accounted for 89% of world aquaculture production in volume in 2010 and this was essentially dominated by the spectacular contribution of China, which accounted for more than 60 percent of global aquaculture production volume in 2010 (FAO, 2012).

It is important to note that many aquatic animal species are native to different ecosystems and are accounted for in the global aquaculture production. This can be illustrated by the following species recorded in 2010: freshwater fishes (56.4%, 33.7 million tonnes), molluscs (23.6% 14.2 million tonnes), crustaceans (9.6%, 5.7 million tonnes), diadromous fishes (6.0%, 3.6 million tonnes), marine fishes (3.1%, 1.8 million tonnes) and other aquatic animals (1.4%, 814,300 tonnes). As shown in Fig.2, tilapia group represents one of the major species or group species in aquaculture production in 2010. Additionally, the production of farmed tilapia is spread wide geographically and its distribution is as follows 72% in Asia (particularly in China and Southeast Asia), 19% in Africa, and 9% in America (FAO, 2012).

Tilapia is ranked after the carp as the most popular farmed food fish in the world and has exceptional characteristics which will help it to exceed carp production in the future. Tilapia is unique because of its easy way to be farmed by the small farmers in developing countries around the world and to be exported to high value markets to be served in great restaurants and grocery stores (Fitzsimmons, 2013). In fact, tilapia is considered to be the most important species of all aquaculture fish of 21st century (Fitzsimmons, 2013). Among the three major farmed fishes, tilapia had the highest production in volume from 2008 to 2012 (Fig. 3). In Addition, as showed in Fig.4 tilapia production from aquaculture has continued to increase from 1984 to 2012 (Fitzsimmons, 2012).

The origin of Chinese name "Wu-Kuo" for Taiwan tilapia came from the surnames of Wu Chen-hui and Kuo Chi-chang who introduced the fish into

Taiwan. Twenty years after its introduction, tilapia had become an important species for Taiwanese people. Thus, many people have acquired fortune by raising tilapia. In a short time, tilapia’s status was changed and became the "national treasure fish" according to the words of fish farmers (Taiwan Panorama, 2006). Taiwan was ranked ninth among the top 10 global producers of tilapia farming in 2012 with a production of 73334 metric tonnes. (Table 1) (FAO, 2014, retrieved by Tacon, 2014). Furthermore, from the Fig.5, Taiwan was ranked in the top ten (10) producing countries of tilapia in the world in 2010 (Fitzsimmons, 2011).

Taiwan has a history in aquaculture which spans 3 centuries. The aquaculture industry is very important because it represents a source of animal protein and income generation for many people (Lee, Liao, and Hwang, 2006). Since tilapia was introduced to Taiwan in 1946, its contribution to the Taiwanese economy has been remarkable. It has allowed the fish farmers to infiltrate key markets such as: Japan and the United States (Taiwan Panorama, 2006). Taiwan was ranked sixth among the seven largest global producers of tilapia from 1996 to 2005 with a production varying from 44,756 to 83,435 tons (Norman and Bjørndal, 2009). Further, Taiwan was among the top 10 tilapia-producing countries in 2010 (Fitzsimmons, 2011), and the total production accounts for 20 to 25% of the total aquaculture production (Grabacki, 2011). In 2010, the annual tilapia production in Taiwan rose to 74,896 tons which had an estimated value of US $117 million (Zajdband, 2012). Tainan County, located in the south of Taiwan, produces almost one third of the total tilapia production on 2,260 hectares of land. Other counties that contribute to aquaculture production include Chiayi, Yulin, Kaohsiung and Pingtung.

The profitability of tilapia farming in any production system can be influenced by environmental conditions. Tilapia farming is profitable, but the costs of production vary considerably across countries, production environments, and culture systems (Gupta and Acosta, 2004). The large variation among these factors leads to differences in quality. Operation costs also affect production and profits (Norman and Bjørndal, 2009a), thus, economic efficiency of tilapia farming in Taiwan varies with geographical location and production scale (farm size). Moreover, taking into account of the importance of tilapia as the number one among the top fish species in Taiwan aquaculture (Table 2) (Liao and Leano, 2010, retrieved by Macenat 2011), there would be interesting to investigate the impacts of geographical location and production scale on tilapia grow-out farming through an economic evaluation.

1.2 Theoretical Framework of the Study

As this study relies on production units that are normally represented by the tilapia grow-out farming, the "Producer Theory" described and widely used in microeconomics is applicable. Microeconomics is a tool used to examine the behavior of individual consumers and firms, is divided into consumer demand theory and producer theory. Microeconomic analysis devotes itself to informing business decisions or formulating public policies (Rodrigo Chris, 2012). Production, one of the basic components of microeconomic theory, is associated with the use of natural resources to produce goods that are then put at the disposal of consumers through various services efforts. Thus, the producer (tilapia farmer) is defined as a decision-making entity that converts inputs by means of production into outputs, and it is generally assumed that the producer desires to maximize the profits of the firm (Sage, 1983).

1.3 Objective of the Study

1.3.1 General Objective

The objective of this research is to make an economic evaluation of tilapia grow-out farming in Taiwan for the year 2008 and to estimate the effects of production scale (farm size), geographical location and their interaction on input intensity and varied profitability variables.

1.3.2 Specific Objectives

- To describe the current situation of tilapia sector in the world in general, particularly in Taiwan through consultation of existing documents;
- To determine the production scale and geographical location effects on input intensity and varied profitability variables of tilapia grow-out farming in Taiwan by using MANOVA;
- To indicate among the sampled tilapia grow-out farming which of them show the best economic results in terms of input intensity and varied profitability by applying principal component analysis with visual aids;
- To determine the correlation level between the economic variables (input intensity and varied profitability) of tilapia grow-out farming in Taiwan by employing the correlation matrix;
- To apply Mahalanobis distance and the discriminant function analysis to estimate the distance between the six (6) groups (based on production scale and location) by using input intensity and varied profitability variables and to indicate which group shows the best economic performance with visual aids;

- To investigate the relationship between the biological and economic variables of tilapia grow-out farming in Taiwan by applying the canonical correlation analysis;
- To apply Cobb Douglas production function to estimate the quantitative relationship between inputs and output in tilapia grow-out farming in Taiwan;

1.4 Research Hypotheses

A hypothesis is a tentative explanation that relies on a set of facts and can be tested by investigation. For instance, this study wants to determine if there is an effect of production scale, geographical location and their interaction on the economic performance of tilapia grow-out farming in Taiwan.

The quantitative research is designed in order to test of hypotheses. Secondary data has been used and the techniques of multivariate analysis have been applied to decide whether or not to accept or to reject the hypotheses mentioned below. Accepting a hypothesis is always temporary until new data may cause it to be rejected later. According to the objective of the study, the following hypotheses were tested:

H1: The geographical location, the production scale, and their interaction have a significant effect on the input intensify variables;

H2: The geographical location, its interaction with the production scale have a significant effect on the varied profitability variables;

H3: The large scale in southern and middle Taiwan is more profitable than the small scale in northern Taiwan with regard to input intensity and varied profitability variables;

H4: The six (6) groups of tilapia grow-out farming are significantly distant from each other by referring to input intensity and varied profitability variables;

H5: In terms of management, the biological variables and economic variables are significant and strongly correlated;

H6: There exist diseconomies of scale in tilapia grow-out farming in Taiwan.

Cooper and Schindler (2003), reported by (Oloo, 2011), indicate that a good hypothesis should be adequate for its purpose, testable and better than its rivals.

1.5 Limitations of the Study

The completion of this study has required quantitative and qualitative data. These data were obtained from a secondary source, which were attained from the memory of fish farmers. Therefore, some imperfections might occur. Moreover, the author lacked access to the constraints expressed by farmers through the obtained secondary data; the size of the sample was not very large due to incomplete data and outliers, all those could limit the recommendations of the author.

II. LITERATURE REVIEW

2.1 History of World Aquaculture

The Chinese society was one of the first to raising fish and cultivating aquatic plants prior to 1,000 BC. In 475 BC, the "aqua husbandry" has been described in Chinese literature. The common carp was farmed because of its high production volume. Therefore, China became the global leader of fish farming, especially in Asia. Some old practices of aquatic animal culture have been tested in captivity. Assyrians had designed river dams, implemented lakes that held fish resources, and built fish ponds for sacred and commercial uses (Nash, 2001).

Asia is considered as the place where the Seaweed was farmed for the first time around four hundred (400) years ago. In the nineteenth century, the natural history study was elaborated and relied on some important aspects as: classification, selective breeding, and evolution. In 1852, a French team succeeded in artificially fertilizing trout eggs. This was the first fish hatchery at Huningue, which served to distribute eggs to European rivers. Following this, freshwater hatcheries multiplied. Thus, the produced fries were used to sow the coastal regions. Some years later (1872), the common carp was introduced into California through Germany. America, owing to its vast water resources, fertilized fish eggs were spread worldwide (Nash, 2001).

2.2 History of Tilapia

Nile tilapia (Oreochromis niloticus) was one of the first farmed fish species. Reports related to Egyptian tombs suggest that Nile tilapia have been cultured for more than 3,000 year (Norman and Bjørndal, 2009). In reference to biblical verses about the fish that has been used by Jesus-Christ to feed a multitude of people, tilapia was called “Saint Peter’s fish”. Among the fish species used in aquaculture, the Nile tilapia is considered as the dominant farmed species in Africa (Popma and Masser, 1999), and its photo is shown in the Fig. 6 (FAO, 2005).

Tilapia has the ability to develop in poor quality water as well as to feed on a wide variety of natural organisms. These characteristics present a great advantage for farming. However, tilapia productivity decreases in water temperature below 10 to 11.11^{o}C. This represents one of the major biological constraints to the development of commercial tilapia farming in cold areas. Furthermore, the early sexual maturity prevents the tilapia from reaching a market size that is generally recommended in commercial scale. This also represents another biological constraint to the development of commercial tilapia farming (Popma and Masser, 1999).

2.3 Taxonomy of Tilapia

The generic name used to describe the group of native cichlids to Africa is tilapia. In this group, three major farming genera are included such as: Oreochromis, Sarotherodon and tilapia. Nevertheless, some characteristics related to reproductive behavior have been distinguished among the three genera. The tilapia species hold the ability to build themselves their nest and the fertilized eggs are secured by the brood parent. With regards to species of Sarotherodon and Oreochromis, they use their mouth as brooders and the egg fertilization is carried out by parents. Notice that, only females of Oreochromis species use their mouth for brooding; on the contrary Sarotherodon species, either male or female use their mouth as brooder (Popma and Masser, 1999).

During the last half century, the tropical and semi-tropical world begun to farm tilapia. Nowadays, 100 percent of tilapia farmed in commercial scale outside of Africa belongs to the genus Oreochromis. Some species originate from the genus Oreochromis are less farmed: Blue tilapia (O. aureus), Mozambique tilapia (O. Mossambicus) and the Zanzibar tilapia (O. urolepis hornorum) (Popma and Masser, 1999).

Over time, within the last 30 years, the scientific appellations of tilapia species have been revised several times. Thus, this was the source of some confusion among people. For instance, the scientific name of the Nile tilapia has been given as Tilapia nilotica, Sarotherodon niloticus, and currently as Oreochromis niloticus (Popma and Masser, 1999).

2.4 Environmental Requirements for Farming Tilapia

Among the cultured freshwater fish in the world, tilapia is known for its tolerance to high salinity, high water temperature, low dissolved oxygen, and high ammonia concentrations.

2.4.1 Salinity

The brackish water is one of the types of ecosystem where tilapia can be grown because of its tolerance to high salinity. Among the commercial tilapia species that are tolerant to high salinity, the Nile tilapia is the least tolerant to the salinity. However, this does not prevent it from growing well at a range of salinity up to 15 ppt. Furthermore, some tilapia species, for instance Blue tilapia, grow well and tolerate salinity levels up to 20 ppt, and the Mozambique tilapia grows well at ranges of salinity close to seawater. Therefore, a preference to saltwater has been identified for the Mozambique tilapia. However, the reproductive performance of some lines of the Mozambique tilapia begins to decline at salinities above 10 to 15 ppt. The salinity levels include 10 and 15 ppt are acceptable for the reproduction of the Blue and Nile tilapias, but they perform better at salinities below 5 ppt (Popma and Masser, 1999).

2.4.2 Water temperature

The tilapia farming at commercial scale is highly limited in the temperate regions due to low temperatures. For most tilapia species, 10 to 11^{o}C is the lower lethal temperature for a few days to survive, with the exception of the Blue tilapia which can tolerate temperatures around 8.89^{o}C. The feeding of tilapia is closely linked to the water temperature. For instance, when the water temperature drops below 17.22^{o}C, tilapia stops feeding. However, when the water temperature reaches 26.67^{o} C and more, the reproduction stage is the best and stops below 20^{o}C. Indeed, 29.44 to 31.11^{o}C is the optimal water temperature for tilapia growth (Popma and Masser, 1999).

2.4.3 Dissolved Oxygen Concentrations

Among the farmed fish, tilapia is only one fish species that can survive in water where the dissolved oxygen (DO) concentrations are less than 0.3 mg/L. The results of research studies mentioned that tilapia developed better by using aerators which help to prevent DO concentrations from dropping below 0.8 to 0.7 mg/L in the morning. Even though the tilapia has the ability to survive at low DO concentration, it would be fundamental to manage the pond cultures in order to maintain the DO concentrations above 1 mg/L. Therefore, some physiological and pathogenic aspects such as: metabolism, growth and disease resistance decrease when the DO concentration drops below 1 mg/L for a relatively long time (Popma and Masser, 1999).

2.4.4 Ammonia Concentrations

Tilapia subjected to concentrations of un-ionized ammonia higher than 2 mg/L in culture water for a few days can result in considerable mortality. Nevertheless, more and more fishes adapt to sub lethal levels, more mortality reductions are observed and they can survive at higher un-ionized ammonia concentrations up to 3 mg/L for 3 or 4 days. It is important to note that un-ionized ammonia concentration greater than 1 mg/L during several weeks cause automatic losses, mostly for fry and juvenile in water with low dissolved oxygen concentration. First mortalities appear when tilapia is subjected to concentrations as low as 0.2 mg/L. However, for concentrations as low as 0.08 mg/L of un-ionized ammonia, the food consumption declines (Popma and Masser, 1999).

2.5 Review of Global Tilapia Farming Practices

The upward growth of tilapia industry in the world has been explained by many factors. Additionally, the production methods vary widely from extensive to intensive in more than 80 countries throughout the world (Norman and Bjørndal, 2009). From Africa and Middle East, tilapia, a native species, has become one of the most important fish in terms of production and commercialization in the world. About 4,000 years ago, tilapia farming begun in Egypt. However, the first scientific work on tilapia occurred in Kenya in1924 and then popularize throughout Africa. Late in 1940s, tilapia became an important farmed fish in the Far East, whereas ten years later, it became an important farmed fish in the Americas (Gupta and Acosta, 2004).

Within the last thirty years, progresses have been observed regarding tilapia farming in the world. Based on its high trend in production and commercialization, tilapia is considered as the most important aquaculture species of the 21st century. Tilapia is cultured in about 85 countries in the world, but a high percentage of produced tilapia (98%) is farmed outside their original habitats (Shelton, 2002, retrieved by Gupta and Acosta, 2004). Actually, tilapia farming is dominated by the Far East; however there is an upward trend in Caribbean, Latin America (Gupta and Acosta, 2004).

The augmentation of tilapia production allows it to become one of the most popular farmed fish in the world. Additionally, tilapia production from fishery is also significant. Fifty years ago, tilapia was considered as the "fish of miracles" because it would have solved the protein deficiencies of which developing countries have suffered and at the same time has satisfied the increasing demand for fish in the developed world (Josupeit, 2005).

2.6 Development of Technologies to Tilapia Farming

In the latter half of 20^{th} century, the success in tilapia farming begun with the introduction of techniques being capable of controlling the reproduction stage. In tilapia populations, there is a growth difference between the sexes, because the males grow faster and are more uniform in size than females. In order to get that advantage, the development of monosex tilapia farming occurred. This process is accomplished with several methods such as: manual sexing, direct hormonal sex reversal, hybridization or genetic manipulation. All those methods also contribute to resolving some problems: early sexual maturation and unwanted reproduction (Gupta and Acosta, 2004).

The amelioration of commercial traits and the control of unwanted reproduction in ponds have been strongly influenced by hybridization. Thus, the hybridization of these species such as: Oreochromis (O. urolepis, O. hornorum and O. mossambicus) carried out by Hicking (1960) has resulted in all male hybrids (Lazard, 1996; Shelton, 2002, retrieved by Gupta and Acosta, 2004). Furthermore, to meet the needs of commercial applications of tilapia farming, interspecific crossing based of different culture methods have been applied and it was found that crossing male O. hornorum or O. aureus with O. mossambicus or O. niloticus also resulted in all male or nearly all male progeny (Shelton, 2002, retrieved by Gupta and Acosta, 2004).

In order to improve the important commercial traits of cultured tropical fishes, the genetically improvement of farmed tilapia (GIFT) technology has been developed by basing on traditional selective breeding. Thus, the selection methods used by the GIFT program have resulted in the achieving of between 12 and 17% as average genetic gain per generation over five generations and cumulative increase in growth rate of 85% in O. niloticus (Eknath and Acosta, 1998).

2.7 Tilapia Production Systems

Tilapias are farmed under three production systems which are presented below:

- Local small pond culture;
- Commercial small-scale systems;
- Industrial aquaculture systems.

2.7.1 Local Small Pond Culture

Commonly practiced in tropical countries, the small pond culture operates under an extensive system. This is an important protein source for the local population. In these systems, there is no classification based on fish age. Feeding is not a major cost, very small and is ensured by the kitchen leftovers. Consequently, the production per hectare (Kg/ha) obtained from this type of tilapia culture is very low (0.5– 2 tonnes) (Josupeit, 2005).

2.7.2 Commercial Small-Scale Systems

Mostly used in Asiatic regions, the commercial small-scale is essentially dominated by the semi-intensive production method. In these systems, the ponds are usually stocked with fingerlings but the quality of the broodstock is rather poor. Rice chaff and leftovers are the mean feed used in these systems. In commercial-scale systems, the market size of raised fish is small (250 g). The production is essentially destined for the local market, but a certain amount is allocated to export market (Josupeit, 2005).

2.7.3 Industrial Aquaculture Systems

As for industrial aquaculture systems, they are characterized by an intensive or highly intensive farming and the produced tilapia is destined for the international market. Constant stocking density, high quality of the broodstock and high quality feed, are the key factors which make the difference between the industrial aquaculture systems with the other systems. For meeting to needs of international market, tilapias are harvested at a required size and the fresh fillets are essentially destined for the export markets. Thus, the two big markets targeted are the United States and European. The yield of industrial systems obtained is about 15 tonnes per hectare; on the contrary in recirculation system the yield can be between 150–180 kg per cubic meter of water (Josupeit, 2005).

2.8 Review of Taiwan Tilapia Farming Practices

The Mozambique tilapia (Tilapia mossambica), from Singapore in 1946, was the first tilapia species introduced to Taiwan. This species has a particular characteristic of becoming sexually mature at the age of three months and reproduces quickly. As an illustration, one brood occurs every three to four weeks during the warm season in a culture environment. Even though the total fish biomass produced at harvest can be important, but most of the individuals are very small. In the 1950s, the extensive system was essentially dominated by this species. Furthermore, tilapia was farmed with the rice paddies (Chen, 1990).

After the introduction Mozambique tilapia, four other species were added to the list of tilapia entering to Taiwan such as: the red tilapia (T. nilotica), the blue tilapia (T. aurea), the wami tilapia (T. hornorum) and the tilapia Zilli, latter is totally eliminated from Taiwan aquaculture because of its hybridization with mouth brooding which is mediocre. The other species are mostly used in experimental breeding at various research institutions. In commercial culture, the hybrid tilapias mostly farmed are below:

1) A hybrid is obtained from crossing female T. mossambica and male T. nilotica. This is called Fu-so-yu (Fortune fish);
2) A hybrid from crossing female Tilapia aurea and male T. nilotica. F_1 offspring of this cross tends to be nearly all males;
3) A red hybrid between T. nilotica and a pink tilapia of unknown identity, believed to be an albino mutant of T. mossambica (Chen, 1990).

From 1946 to 1997, many tilapia species have been introduced into Taiwan (Table 4) (Cardona, 2007, retrieved by Dahani, 2011). This created a diversity of tilapia in Taiwanese aquaculture.

2.9 Tilapia Global Supply and Trade

In 2011, 88% of global tilapia productions, estimated at 3.585million tonnes, have been produced by the top ten tilapia producers. From 2010, Indonesia and Brazil were the only countries which have obtained a spectacular growth of 31% and 63%, respectively. A decline of Chinese tilapia production was registered in 2012 due to bad climatic conditions and disease problems (Globefish, 2013).

During the first quarter of 2013, the fresh and frozen tilapia imports that have been collected in about 30 countries have been estimated at USD 200 million, whether 55,000 tonnes. However, there was a decline in tilapia frozen fillets imported by USA. This resulted in a higher import destined to other markets such as: Russia, Iran and Hong Kong (Globefish, 2013).

2.9.1 Tilapia: China Market

Based on FAO data, a moderate increasing in tilapia production has been registered. Thus, tilapia production rose slightly over 1 million tonnes in 2011. A significant amount of Chinese tilapia is essentially destined for domestic market due to the increase of domestic demand. During the first quarter of 2013, tilapia exports from China grew slightly to 67,000 tonnes, estimated at USD 223 million. Frozen fillet was the largest share of exports. Nevertheless, frozen whole fish registered a positive growth (Table 5).

The exports of frozen fillet from China decreased 9% due to its export decline to the USA market; latter represents the major market for the frozen fillet category. Although the exports were shared among the new and emerging markets, they could not collectively absorb the export reductions to the USA market. African countries and the Middle East have increased their share of whole frozen and breaded fillet categories to export market (Globefish, 2013).

2.9.2 Tilapia: USA Market

Tilapia production in the U.S. is mostly performed in the southern states, and more than 75% of the annual production is supplied by recirculating systems (Zajdband, 2012a).US tilapia markets are essentially dominated by imports. It is reported that 95.5% of tilapia consumed in the US was imported, and only 4.5% was produced in the USA (Fitzsimmons, 2010). During the first quarter of 2013, total tilapia imports declined slightly. This is due mainly to the drop of whole frozen and frozen fillet imports (Tables 6 and 7). However, the fresh fillet category has grown from about 26,000 to 72,000 tonnes in 2012 and 2013, respectively. The Latino America countries such as: Honduras, Ecuador and Costa Rica, which together accounted for 80% of fresh fillet for the USA market (Table 8). The share of Colombia to the USA market could be possibly explained by a free trade agreement (FTA) concluded between Colombia and USA in May 2011. In the first quarter of the year, the USA imports of fresh fillet increased because of increasing demand during the Lent period (Table 9).

2.9.3 Tilapia: European Union Market

Within the first quarter of 2013, EU imports of frozen tilapia fillets were 14% higher than those at the same period in 2012 estimated at 4,560 tonnes in volume and USD 16 million in value. The imports of UE were meanly dominated by China with its share of nearly 85%. As for Indonesia, it supplied almost 100% more than in 2012 estimated at 571 tonnes. Other Asian countries such as: Viêt Nam, Thailand and Bangladesh, supplied more to the UE market (Globefish, 2013).

Interesting prices ranging between USD 6 - 7 /kg have been obtained by the tilapia products from Indonesia, Thailand, Malaysia and Ecuador. Additionally, tilapia fillet from the Malaysian producer, Trapia Malaysia, which is certified by ASC has gotten high prices this year. The GenoMar Supreme Tilapia fingerlings have been used by Trapia Malaysia for the fingerling production. Throughout the value chain, every fingerling is categorized, traceable and verifiable for ensuring product quality. Thus, these products were destined for North America, Europe, Asia and domestic markets. However, from China, the average import prices for tilapia products were USD 3.15 /kg (Globefish, 2013).

2.9.4 Tilapia: Taiwan Market

In 2011, Taiwan produced 67,224 tonnes of tilapia on 5,308 ha of which 30,566 tonnes of live weight were exported. On the domestic market, the unit production value was TWD 48.52/kg (USD 1.63/kg) and on the export market the value was TWD 60.05/kg (USD2.0/kg). In return, the value of exports was TWD 37.61/kg (USD1.26/kg) in 2001 (Chiang, 2013).

Tilapia is the dominant export product, exceeding the milkfish. Today, it is the only fish fillet exported to the EU market. In 2011, Taiwan tilapia fulfilled sashimi grade at the export level. The whole fish can be fully used and comprises of 36.5% fillet, 4.0% skin, 3.0% scale, 4.0% trim, 7.0% chin, 5.0% belly, 15%

head, 9.0% bone, 10.5% offal, 4.5% residues and 1.5% blood (Chiang, 2013).The red tilapia was produced for the niche market and the black one as a commodity. Quality is assured with live fish sent to the processing plant. Skinless fillet is cleaned in ozone. Scales are extracted for collagen production. Since 2011, industry has been successful with transformation of tilapia tailfins into a product very similar to the shark fins with the same appearance and texture (Chan, 2011).

In 2013, a ceremony has been organized by the Aquaculture Stewardship Council (ASC) at the European Seafood Exposition in Brussels with the Taiwan Frozen Seafood Industries Association and the Taiwan Tilapia Alliance (T2A) in which 11 Taiwanese tilapia farms were certified by ASC.

The average annual tilapia production in Taiwan is 70,000 tonnes, of which 60% is destined for USA, Canada, Saudi Arabia and Republic of Korea markets. With regards to frozen tilapia, from January to September in 2013, Taiwan exported 24,189 tonnes. Thus, a production increase of 31% has been obtained in 2013 in comparison with the same period in 2012. Among the frozen categories, whole tilapia accounted for 90%. Additionally, the share of whole frozen tilapia in the exports grew to the most important markets except for Saudi Arabia, Japan and Qatar (Globefish, 2014).

Taiwan receives a better price for its frozen fillets because of the product's high quality. During the review period, an amount of 1,035 tonnes of frozen fillet were sold at an average export price of USD 8.35 /kg, mostly to the Republic of Korea, USA and Japan markets. Additionally, sashimi exported to the Japanese market got an average price of USD 10.20/kg (Globefish, 2013).

III. METHODOLOGY

3.1 Description of the Study Area

Formosa means "Beautiful Island", is the historic name of Taiwan. It is geographically located in the East Asia 108 kilometers from the southeastern coast of China. In terms of altitude, six peaks having over 3,500 meters have been listed of which the highest is Yu Shan with 3,952 meters (12,966 feet). Taiwan is therefore the fourth-highest island in the world. Typhoons are frequent in this island. Every year, Taiwan is struck by an average of four typhoons. The eastern mountains are mostly dominated by forests and the presence of diverse species of wildlife, whereas the northern lowlands are intensively used (Geography of Taiwan, 2014). In December 2013, Taiwan's population was 23,373,517, distributed on 35,980 square kilometers (km^2), making Taiwan the most densely populated country in the world with a population density of 646 people per square kilometer (**km^2**) (Demographics of Taiwan, 2014).

Taiwan's climate is influenced by the East Asian monsoon. A humid subtropical climate is dominant in the northern and central Taiwan. However, southern and south eastern Taiwan are dominated by a tropical monsoon climate. In these parts of Taiwan, seasonal temperature variations are quite stable usually varying from warm to hot. Mostly in winter, an abundant precipitation is registered in the northeast; in contrast the central and southern parts are sunny. Annual precipitations (90%) have been recorded during the summer monsoon in the south against 60% in the north (Geography of Taiwan, 2014).

3.2 Secondary Data Source

Secondary data of tilapia grow-out farming collected in 2008 by the Aquatic Animal Nutrition and Feeding Laboratory of the Aquaculture Department of the National Taiwan Ocean University were used. A stratified random sampling method was applied to the data using geographical location and production scale (farm size). After elimination of incomplete data and outliers, 28 tilapia grow-out farms were selected for analysis. Two levels of production scale, less than 1 hectare for the small scale and between 1 and 6.5 hectares for the large scale were obtained and are then distributed into the 3 geographical locations (northern, middle and southern Taiwan), which resulted in 6 groups of tilapia grow-farms (Table 3 and Fig. 7).

3.3 Variables Definition

Two sets of variables have been considered, the biological variables, which included stocking density and survival rate, and the second set, economic variables, consisted of input intensity and varied profitability variables. The input intensity variables were computed by dividing the individual item cost by the total area in hectares, whereas those of varied profitability were computed by dividing the net revenue by the individual input cost. Additionally, the net revenue or net profit was calculated by subtracting the total cost from total revenue (Brown, 1979). Consequently, five input intensity variables: fry, feed-fertilizer, water-electricity-fuel, labor, and fixed costs were calculated. The fixed cost is composed of loan interest, insurance, and depreciation of pond culture and equipment. The depreciation was calculated by using the straight line method where the initial purchase cost is subtracted from the salvage value, and then divided by the years of useful life (Engle, 2010). Finally, 5 input intensity and 5 varied profitability variables were analyzed. The currency unit used in the study analysis is new Taiwan dollar (NTD), its exchange rate to the unit US dollar is about thirty NTD (1USD = 30 NTD).

3.4 Multivariate Analysis

Multivariate analysis refers to all statistical techniques that simultaneously analyze multiple measurements on individuals or objects under investigation. Therefore, any simultaneously analysis of more than two variables can be loosely considered multivariate analysis (Hair *et al*., 2006).

Multivariate analysis is not often used in literature because it sometimes causes confusions about what multivariate analysis is. Some researchers use multivariate simply to examine relationships between or among more than two variables. Others use the term only for problems in which all the multiple variables are assumed to have a multivariate normal distribution. To truly consider multivariate analysis, all variables must be random and interrelated in such ways that their different effects cannot meaningfully be interpreted separately. Some authors mention that the purpose of multivariate analysis is to measure, explain and predict the degree of relationship among variables (weighted combinations of variables). Thus, the multivariate character relies on the multiple variables (multiple combinations of variables), and not only in the number of variables or observations (Hair *et al.*, 2006).

Therefore, different multivariate statistical methods have been performed in this study.

3.4.1 Multivariate Analysis of Variance (MANOVA)

Multivariate analysis of variance (MANOVA) is an extension of analysis of variance (ANOVA) to accommodate more than one dependent variable. It is a dependence technique that measures the difference for two or more metric dependent variables based on a set of categorical (nonmetric) variables acting as independent variables (Hair *et al.,* 2006).

Like ANOVA, MANOVA is interested with differences between groups (or experimental treatments). ANOVA is termed a univariate procedure because we use it to assess group differences on a single metric dependent variable. MANOVA is termed a multivariate procedure because we use it to assess group differences across multiple metric dependent variables simultaneously (Hair *et al.,* 2006).

Based on the concepts exposed above, a two way MANOVA (Johnson and Wichern, 1988) was applied to evaluate the effect of production scale, geographical location and also their interaction on the studied variables that are input intensity and varied profitability.

3.4.2 Principal Component Analysis (PCA)

The technique of principal component analysis was first described by Karl Pearson (1901). A description of practical computing methods came much later from Hotelling (1933). The objective of the analysis is to take p variables X_1, $X_2, \ldots, X_p$ and find linear combinations of these to produce indices $Z_1, Z_2, \ldots, Z_p$ that are uncorrelated. The lack of correlation is a useful property because it means that the indices are measuring different 'dimension' in the data. However, the indices are also ordered so that Z_1 displays the largest amount of variation, Z_2 displays the second largest amount of variation, and so on. Namely, var $(Z_1) \geq$ var $(Z_2) \geq \ldots \geq$

var (Z_p), where var (Z_i) denotes the variance of Z_i in the considered data set. The Z_i are called principal components (Manly, 1986).

Thus, a principal component analysis (Manly, 1986) was conducted to investigate the individual economic performance with quantitative comparisons and visual aids. This will also allow to observe the individual distribution of 28 tilapia grow-out farms according to the retained principal components.

3.4.3 Discriminant Function Analysis

Discriminant analysis is the appropriate statistical technique for testing the hypothesis that the group means of a set of independent variables for two or more group are equal (Hair *et al.*, 2006).

The usefulness of discriminant analysis is its characteristic to define discriminant function (s) that result in significantly different group centroids, the average discriminant Z score for all group members. The differences between centroids are measured in terms of Mahalanobis D^2 measure, for which tests are available to determine whether the differences are statistically significant (Hair *et al.*, 2006).

The canonical discriminant functions Z_1, Z_2,…, Z_S are linear combinations of the original variables chosen in such a way that Z_1 reflects group differences as much as possible; Z_2 captures as much as possible of the group differences not displayed by Z_1; Z_3 captures as much as possible of the group differences not displayed by Z_1 and Z_2; and so on. The purpose is that the first few functions are enough to account for almost all of the important differences within the groups (Mahalanobis, 1948; Manly, 1986).

Therefore, the analysis of canonical discriminant function (Fisher, 1936; Hair, Anderson, and Tatham, 1987) was used to determine the economic performance of six groups of tilapia grow-out farming visual aids and to figure out which group has the best economic result.

3.4.4 Canonical Correlation Analysis (CCA)

A canonical correlation analysis can be used to investigate the relationships between the two groups of data set (Manly, 1986). It is a statistical tool that allows an examination of the correlation between two linear combinations of the variables by using two data sets.

Firstly, the purpose is to find the first pair of linear combinations that has the largest correlation. Then, to determine the second pair uncorrelated with the previously selected pair. The pairs of linear combination are called the canonical variables, and their correlation is called canonical correlation (Johnson and Wichern, 2002).

Therefore, based on the exposed concept above, a canonical correlation analysis was used to investigate the relationship between the two sets of variables such as: biological variables (stoking density and survival rate) and economic variables (fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost intensities) in order to determine the relationship level in terms of management performance.

3.4.5 Cobb-Douglas Production Function

The Cobb-Douglas functional form of production functions is mostly used in economics to establish the relationship of an output to inputs. It was proposed by Knut Wicksell (1851-1926) and tested later against statistical evidence by Charles Cobb and Paul Douglas in 1928 (Tan, 2008).

The Cobb-Douglas production function is stated by the model as follows:

$P(L, K) = bL^{\alpha}K^{\beta}$

Where:

- P = total production (the monetary value of all goods produced in a year)
- L = labor input
- K = capital input
- b = total factor productivity
- α and β are the output elasticities of labor and capital, respectively. These values are constants determined by available technology.

Thus, the Cobb- Douglas production function (Smith, 1982) was applied to investigate a quantitative relationship between the inputs (input intensity variables) and the output (return) of tilapia grow-out farming in Taiwan. This can help to measure the responsiveness of output to unit increase of inputs.

A computer software developed by SAS Institute (2013), version 9.3, was used for all statistical analyses.

IV. RESULTS AND DISCUSSION

4.1 Descriptive Statistics and Two-way MANOVA

The total production cost was divided into two categories: variable costs and fixed costs. The variable costs, as the name implies, vary with the level of production, whereas the fixed costs are not affected (Pillay and Kutty, 2005). Therefore, the variable costs include five individual costs such as: fry, feed-fertilizer, water-electricity-fuel, labor and maintenance-repair costs. However, the fixed costs comprise of loan interest, insurance and depreciation of pond culture and equipment. Among the 6 input intensity variables displayed in Fig.8 with their respective percentages: fry (61%), feed-fertilizer (14%), water-electricity-fuel (7%), labor (7%), fixed cost (6%) and maintenance-repair (5%), only five of them which accounted for 95% of production cost were retained by this study, with the exception of maintenance-repair cost due to its slight percentage in the production cost. The fixed costs comprised of: loan interest, insurance and depreciation of pond culture and equipment, was small and accounted for only 6% of production cost. This could be explained by the low depreciation of pond culture and equipment due to their obsolescence. These findings agreed with (Miao and Tang, 2002) who reported that most systems of pond culture in Taiwan are quite old (15 years or more). Hatch and Feng (1997) found that intensive farming is characterized by low fixed costs per kilogram, but have high variable cost mainly for feed and water quality maintenance. In this study, feed-fertilizer and fry were the two major variable costs and together they accounted for 75% of production cost. The farming cost in Taiwan aquaculture is largely dominated by the variable costs including feed, fry, water and electricity which account for more than 65% of the production cost (Miao and Tang, 2002). The costs of fry, feed, water and electricity are the most significant expenditures in intensive aquaculture. In many cases they account for more than 50% of the total production cost (Shang, 1990). Tables 10 and 11 indicated the descriptive statistics of input intensity and varied profitability variables, respectively. A comparison of input intensity variables between the 3 geographical locations: northern, middle and southern Taiwan and among the 2 production scales: small scale and large scale are shown in Fig.1 and 2, respectively.

A two-way MANOVA was applied to input intensity variables. The factors production scale, geographical location and their interactions had a very significant effect (P value = <0.0001) on the input intensity variables (Table 12). The "Duncan's multiple range test" was then performed (Duncan, 1955), and results indicated that the small scale in northern Taiwan had the highest input intensity for overall variables; whereas the large scale in the south had the lowest (Table 13). Pillary and Kutty (2005) reported smaller farm size may result in higher production cost. With regards to geographical location, northern Taiwan had the highest input intensity for overall input intensity variables: fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost; whereas the southern had the lowest input intensity for the overall variables (Table 13).

Indeed, the farmers who operated large scale farms in southern Taiwan had lower input costs per unit area than those who operated small scale farms in the north. This could be explained by the price of inputs, due to transport, mostly for feed input, which could vary according to the location and the size of the farm. The tilapia operations in Taiwan are located primarily in the south (Zajdband, 2012). Pillary and Kutty (2005) reported that smaller farm size may result in higher production cost.

A two-way MANOVA was also applied to varied profitability variables. It indicated that production scale had no significant effect on varied profitability variables; however, the geographical location and its interaction with the production scale had a significant effect (Table 5). The efficiency and economic performance were highly influenced by the farming scale or farm size (Pillay, 1996; Roy *et al*., 2002). The "Duncan's multiple range test" was performed (Duncan, 1955). Thus, the highest unit profitability from feed-fertilizer, water-electricity-fuel and labor were found in southern Taiwan, whereas the middle had the highest from fry, and fixed cost profitability. However, northern Taiwan had the lowest unit varied profitability for overall variables (Table 16).

Indeed, the large scale in southern and middle Taiwan had the highest unit varied profitability (Table 17). As reported by (Shang, 1990), there is a relationship between profitability and the level of production. This indicated that the farmers operating under large scale in southern and middle Taiwan got more profit per unit area (new Taiwan dollar per hectare). These findings might be explained by the climate differences more specifically the temperature difference that exists among the three geographical locations. This explanation can be supported by Wurts (2000) who reported that the tilapia performance is best in a temperature range 22 - 32ºC and its growth and feeding slow is observed when water temperature drops below 21ºC. According to Executive Yuan (2014), Taiwan's annual average temperature is about 24°C in the south and 22°C in the north. Additionally, the best economic performance of these groups of tilapia grow-out farming (large scale in southern and middle Taiwan) might be also explained by the choice of aimed markets domestic or export. In Taiwan the largest exporter of tilapia is the Kouhu Fisheries Cooperative comprised of more than 200 fish farm operators from three counties in southern Taiwan with a combined pond area of 2,300 hectares. These farms represent a quarter of Taiwan's total tilapia farming area (Chan, 2011). According to Huang *et al.*, (2004), there are two market sizes for tilapia in Taiwan. For domestic consumption, the tilapia market size is about 600 grams, while the export fillet market is approximately 1 kilogram.

4.2 Principal Component Analysis (PCA)

After performing the PCA, all the correlation coefficients of the input intensity variables were summarized in Table 9, called correlation matrix. In terms of input intensity, the strongest relationship was obtained between fry and labor (r=0.8676) and followed by water-electricity-fuel and feed-fertilizer (r=0.8504) (Table 18). Moreover, fry had developed a strong relationship with feed-fertilizer, water-electricity-fuel and fixed cost based on their correlation coefficients (r=0.8182, r=0.7743 and r=0.7403), respectively.

The purpose of principal components analysis is to take p variables X_1, X_2,…, X_p and to find linear combinations of these to produce indices Z_1, Z_2,..., Z_p that are uncorrelated. The lack of correlation is a useful property because it means that the indices are measuring different 'dimensions' in the data. However, the indices are also ordered so that Z_1 displays the largest amount of variation, Z_2 displays the second largest amount of variation. That is, var $(Z_1) \geq$ var $(Z_2) \geq \ldots \geq$ var (Z_p), where var (Z_i) denotes the variance of Z_i in the data set considered. The Z_i are called the principal components (Manly, 1986).

A principal component analysis was applied by using the five original variables such as: fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost intensities. After the standardization of the original variables, all had a variance of 1.0. The two principal components (I_1 and I_2) had a variance of 4.1126 and 0.3899 respectively and together accounted for 90.05% of the total variation in the data set. The other principal components accounted for a trivial amount of variation (Table 8). The first and the second principal components analyses (I_1 and I_2) accounted for 82.25% and 7.80% of the total variation, respectively. With regards the first principal component (I_1), the eigenvectors, the coefficients of original variables: fry (0.4576), feed-fertilizer (0.4478), water-electricity-fuel (0.4456), labor (0.4587) and fixed cost intensities (0.4254) were all high (Table 8). Consequently, any tilapia grow-out farm having a high score in I_1 would spend more on input per unit area in fry, feed-fertilizer, water-electricity-fuel, labor and fixed costs. For the second principal component analysis (I_2) the eigenvectors, the coefficients of labor (0.2584) and fixed cost (0.7036) were positively high, in contrast those of feed-fertilizer (-0.5494), water-electricity-fuel (-0.3686) were negatively high. This indicated that any tilapia grow-out farm having a high score in I_2 would spend more on input per unit area in labor and fixed costs, but less in feed-fertilizer and water-electricity-fuel costs (Table 19). The two principal components analyses presented below (I_1 and I_2) are of linear combinations of original variables: fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost intensities (Table 8):

$$\mathbf{I_1} = 0.4576FR + 0.4478FF + 0.4456WEF + 0.4587LR + 0.4254FC$$

$$\mathbf{I_2} = -0.0167FR - 0.5494FF - 0.3686WEF + 0.2584LR + 0.7036FC$$

Figure 11 shows a plot of the two principal components analysis (PCA) (I_1 and I_2) using the 5 input intensity variables. Regarding to the relative position of these tilapia grow-out farms: A26, A27, A28 and A29, had high scores for I_1 and operated under small scale in northern Taiwan. Generally speaking, this indicated that those farms might spend more on unit input per unit area in overall input intensity variables. This implies that based on their extreme scores on I_2, tilapia grow-out farms A26 and A28 could spend more on input per unit area in labor and fixed cost, but less in feed-fertilizer and water-electricity-fuel. Therefore, the results from PCA suggested that the tilapia grow-out farm operating under small scale in northern Taiwan had the highest unit input intensity for overall input intensity variables. In other words, they spent more money per unit area (hectare). This might be explained by the price of inputs due to transports, which could be different from northern to southern Taiwan. According to Zajdband (2012), the tilapia operations in Taiwan are located primarily in the south of the country. These findings are in agreement with Duncan's multiple range test result (see above).

After performing the PCA, all the correlation coefficients of the varied profitability variables were summarized in Table 20, called correlation matrix. In terms of varied profitability, the strongest relationship was found between feed-fertilizer and water-electricity-fuel (r=0.6472). Moreover, labor has developed more or less strong relationship with fixed cost and feed-fertilizer based on their correlation coefficients (r=0.5124) and (r=0.4760), respectively (Table 20).

A principal component analysis was also applied to varied profitability variables. After the standardization of the original variables, all had a variance of 1.0. The two principal components (P_1 and P_2) had therefore a variance of 2.4565 and 0.9847 respectively and together accounted for 68.82% of the total variation in the data set (Table 21). P_1 and P_2 accounted for 49.13% and 19.69% respectively of the total variation. As for the first principal component (P_1), the eigenvectors, the coefficients of varied profitability variables: feed-fertilizer (0.5061), water-electricity-fuel (0.4659), labor (0.4904), fixed cost (0.4445) and fry (0.2975) were high. Consequently, any farm having a high score in P_1 might get more profit per unit area for overall varied profitability variables. For the second principal component analysis (P_2), the eigenvectors, namely, the coefficients of fry (0.6828), labor (0.2564) and fixed cost (0.2428) profitabilities were positively high, in contrast those of water-electricity-fuel (-0.4854) and feed-fertilizer (-0.4163) profitabilities were negatively high (Table 9). This indicated that any tilapia grow-out farm having a high score in P_2 could get more profit per unit area from fry, labor and fixed cost profitabilities, but less from water-electricity-fuel profitability followed by feed-fertilizer profitability. The two principal components analyses presented below (P_1 and P_2) are of linear combinations of original variables: fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost profitabilities (Table 21):

$$\mathbf{P_1} = 0.2975FR + 0.5061FF + 0.4659WEF + 0.4904LR + 0.4445FC$$

$$\mathbf{P_2} = 0.6828FR - 0.4163FF - 0.4854WEF + 0.2564LR + 0.2428FC$$

Fig.12 shows a plot of two principal components analyses (P_1 and P_2) using the 5 varied profitability variables. Regarding to the relative position of tilapia grow-out farms such as: F87, F54, F50, F57, F58, F51, F37, F46, F39 and F45, had high score for P_1 and operated under large scale in southern Taiwan. Generally speaking, this indicated that those farms might get more profit per unit area from overall varied profitability variables. This implies that based on its extreme score on I_2, tilapia grow-out farm F87 could get more unit profit from fry, labor and fixed cost, but less from water-electricity-fuel and feed-fertilizer. Thus, the results from PCA suggested that the tilapia grow-out farm that operated under large scale in southern Taiwan got more profit per unit area for overall varied profitability variables. This might be explained by average annual temperature ($22^{O}C$) in southern Taiwan (Executive Yuan, 2014) which is favorable for raising tilapia and also by the targeted market choice (domestic or export).

4.3 Discriminant Function Analysis

To measure Mahalanobis distance represents a way to determine the correlations between concerned variables and to evaluate how different two objects are. The idea is that if two objects have similar mean measurements, then they are "close", whereas if they have different mean measurements, then they are 'distant' from each other (Miao and Tang, 2002). Based on the Mahalanobis distance, the difference or similarity was measured between the six groups of tilapia grow-out farm in order to determine if each group is significantly distant from each other with regards input intensity variables. Therefore, if α probability was set to 5%, so the F group (large scale - south) is significantly distant from the five others groups, namely A (small scale - north), B (small scale - middle), C (small scale - south), D (large scale - north) and E (large scale - middle) groups; the D group is significantly distant from the A, B, C and E groups; and finally the A group is significantly distant from the B, C and E groups. However, the others groups are not significantly distant from each other (Table 22).

With regards varied profitability variables, the groups are not significantly distant from each other except for: the F (large scale - south) group is significantly distant from the A (small scale - north), B (small scale - middle), C (small scale - south), D (large scale - north), E (large scale - middle) (Table 23).

Canonical discriminant function is useful to determine the functions of variables X_1, X_2,…, X_p that in some sense separate the **m** groups as well as possible. The simplest approach consists to take a linear combination of the original variables (X) chosen in such a way that Z_1 reflects group differences as much as possible; Z_2 captures as much as possible of the group differences not taken into account by Z_1. The main purpose is that the first few functions are sufficient to account for almost all of the important group differences (Manly, 1986).

For the input intensity variables, two canonical variables statistically significant at $\alpha = 0.001$ were retained (Table 24). Based on the raw canonical coefficient, these two canonical functions are presented below (Table 25):

$$\mathbf{Can_1} = 0.0000170119FR + 0.0000039134FF - 0.0000139776WEF - 0.0000053422LR + 0.0000112819FC$$

$$\mathbf{Can_2} = - 0.0000086096FR + 0.0000031059FF + 0.0000267366WEF - 0.0000098700LR - 0.0000010462FC$$

From Table 25, Can_1 had a high positive coefficient for fry (FR) and fixed cost (FC) intensities, however negative for water-electricity-fuel (WEF) intensity. This indicated that there was a contrast between fry and fixed cost intensities with water-electricity-fuel intensity. Conversely, Can_2 had a high positive coefficient for water-electricity-fuel while negative for labor intensity. This also indicated that there was a contrast between water-electricity-fuel and labor intensities. In this case, any group of tilapia grow-out farms that had a high coefficient for fry intensity followed by fixed cost intensity, and water-electricity-fuel intensity would have a high positive score in Can_1 and Can_2 respectively. On the other hand, any group of tilapia grow-out farm that had a high coefficient for water-electricity-fuel and labor intensities would have a high negative score for $Can_1$and Can_2, respectively.

Fig.13 shows a plot of the input intensity variables of 6 groups of tilapia grow-out farm for the two canonical discriminant functions (Can_1 and Can_2) which accounted for 88.13 and 9.47% of the total group variation, respectively. The A group had the highest score for Can_1. Therefore, the results from discriminant function analysis suggested that the tilapia grow-out farm that operated under small scale in northern Taiwan might spend more on input costs per unit area.

In regards to varied profitability variables, two canonical variables were also retained by this study but only the first one was statistically significant at $\alpha = 0.005$ (Table 12). Based on the raw canonical coefficient, the two canonical functions retained are presented below (Table 27):

$$\mathbf{Z_1} = - 0.036364574FR + 0.5971755427FF + 0.118135523WEF + 0.073566863LR - 0.036891780FC$$

$$\mathbf{Z_2} = 0.070271653FR - 0.018587631FF + 0.005075910WEF - 0.007917002LR + 0.026216819FC$$

From Table 27, Z_1 had a high positive coefficient for feed-fertilizer (FF), water-electricity-fuel (WEF) and labor (LR) profitabilities, but had negative for fry and fixed cost (FC) profitabilities. This showed that there was a contrast. However, Z_2 had a high positive coefficient for fry (FR) and fixed cost profitabilities, but negative for feed-fertilizer profitability. This also indicated that there was a contrast. In this case, any group of tilapia grow-out farm which had a high coefficient for feed-fertilizer profitability followed by water-electricity-fuel and labor profitabilities and for fry profitability followed by fixed cost profitability would have a high positive score in Z_1 and Z_2, respectively. On the other hand, any group of tilapia grow-out farm which had a high coefficient for fry profitability followed by fixed cost profitability, and for feed-fertilizer profitability would have a high negative score for $Z_1$and Z_2, respectively.

Fig.14 shows a plot of the varied profitability variables of 6 groups of tilapia grow-out farms for the two canonical discriminant functions (Z_1 and Z_2) retained which accounted for 87.34 and 11.50% of the total group variation, respectively. The F group had the highest score for Z_1. Therefore, the results from discriminant function analysis suggested that the tilapia grow-out farm that operated under large scale in southern Taiwan might get more profit per unit area. These findings are in agreement with Duncan's multiple range test result (see above).

4.4 Canonical Correlation Analysis (CCA)

A canonical correlation analysis was used to investigate the relationship between two groups of variables. Indeed, a canonical correlation analysis is a generalization of multiple regression in which several Y variables are simultaneously related to several X variables (Manly, 1986). The canonical correlation between the first input intensity index (P_1) and the first manageability index (M_1) was (r=0.83) and it is statistically significant at (P value=0.0002) (Table 14). This indicated that there was a strong reciprocal relationship between P_1 and M_1. Nevertheless, the second pair of canonical correlation has not been considered because of its statistical insignificance.

The first pair canonical variates (P_1, M_1) displayed below is a linear combination of input intensity and biological variables respectively (Table 28):

$\mathbf{P_1}$ = 0.5838FR - 0.1912FF - 0.1188WEF + 0.2249LR + 0.5202FC

$\mathbf{M_1}$ = 1.2387SD + 0.8244SR

The first canonical variable for the economic variables displayed in Table 28 is a weighted difference of fry (0.5838), fixed cost (0.5202), labor (0.2249), feed-fertilizer (-0.1912) and water-electricity-fuel (-0.1188), with more emphasis on fry intensity. This revealed any increase in fry intensity would involve increasing the first input intensity index (P_1). This relationship of ratio agreed with a positive correlation between fry intensity and the first input intensity index P_1 (r=0.9155) and the first manageability index (M_1) (r=0.7614), respectively (Table 29). The first canonical variable for the biological variables displayed in Table 28 is also a weighted difference of stocking density (1.2387) and survival rate (0.8244), with more emphasis on stocking density. This also revealed any increase in stocking density would involve increasing the first manageability index (M_1). The coefficient of stocking density (SD) in the M_1 function was higher (1.2387) than that of survival rate (0.8244) (Table 28). It seems that the survival rate had a low effect on the first manageability index (M_1). This statement was then confirmed by a low correlation between survival rate (SR) and the first input intensity index (P_1) (r= 0.0733) and the first manageability index (M_1) (r= 0.0881), respectively (Table 29). In other words, the survival rate did not represent a major problem to the management of tilapia grow-out farming in Taiwan. Indeed, the highest coefficients were found for stocking density variable (1.2387) in the M_1 equation and fry intensity variable (0.5838) in the P_1 equation (Table 28). Thus, there was a strong reciprocal relationship between stocking density and fry intensity. As a result, increasing stocking density would result in an increase in the fry cost per hectare. As reported Pillay (1990) and Sevilleja (2000), the application of efficient farm management is a key element to successful aquaculture operation. Additionally Shang (1990) noted that biology is one of the elements which affect aquaculture economics.

4.5 Cobb Douglas Production Function

The Cobb-Douglas production function was applied to estimate though varied methods of model selection including forward selection, backward elimination, stepwise, maximum R^2 improvement, adjusted R^2 selection and Mallows' Cp selection, the key factors among the input intensity variables that are able to affect the return (RE). All of these selection methods quoted above provided the following model:

$$\textbf{Return} = 2.2731\ (\textbf{Labor})^{0.2847}\ (\textbf{Feed-fertilizer})^{0.2576}\ (\textbf{Water-electricity-fuel})^{0.2134}$$

The probabilities of partial elasticities of explanatory variables are statistically significant at 5%. Thus, the probability of labor, feed-fertilizer and water-electricity-fuel are as follows: P values = 0.0003, 0.0116 and 0.001. The coefficients of labor and water-electricity-fuel intensities are significantly different from zero, with a **P**-value at 0.1% level according to F-test, while the coefficient of feed-fertilizer intensity is significantly different from zero, with a **P**-value at 1% level (Table 30). Therefore, based on the probability of those explanatory variables, the model is highly significant ($p<0.01$). Consequently, labor, feed-fertilizer and water-electricity-fuel intensities were the mean key factors that affected the return of tilapia grow-out farming. The Cobb-Douglas production function shown in (Table 30) gave an adjusted R^2 of 0.91, implying that 91.21% of the variation in tilapia return is explained by the explanatory variables displayed in the model. These findings were in agreement with Inoni (2007) and Asmah (2008) who indicated that stocking density, feed, fertilizer, labor were significant factors that affected fish yield. The Cobb-Douglas production function mentioned in Table 30 indicated that a diminishing return was strongly determined by the inputs: labor, feed-fertilizer and water-electricity-fuel intensities. In this case, the production elasticities (coefficients) are 0.2847, 0.2576 and 0.2134, respectively, for labor, feed-fertilizer and water-electricity-fuel intensities (Table 30). As a result, a one percent increase in labor, feed-fertilizer and water-electricity-fuel intensities will result in a 0.2847, 0.2576 and 0.2134% increase in return (Table 30). Furthermore, the sum of previously obtained coefficients is 0.7557 (Table 30). It revealed a diminishing return to economy of scale exists. In this case, a doubling of all the three inputs will be smaller the return (Shang, 1990).

V. CONCLUSION AND RECOMMENDATIONS

The results of this study confirmed that production scale, geographical location and their interactions have a significant effect on the input intensity variables of tilapia farms. Furthermore, the geographical location and its interaction with the production scale had a significant effect on varied profitability variables. The farmers operating large scale farms in southern Taiwan were more efficient in terms of input intensity used and profit generated. There was a very significant relationship between economic variables and biological variables according to correlation canonical analysis. The stocking density and the fry intensity were found highly correlated. A diminishing return has been determined by labor, feed-fertilizer and water-electricity-fuel. The Cobb –Douglas production function revealed that there were diseconomies of scale in tilapia grow-out farming in Taiwan.

Finally, the results led to the acceptation of previously expressed hypotheses, except the 4^{th} one for which the hypothesis is rejected (Table 31).

From the results found and the limitations encountered, some recommendations are expressed as:

1. It would be interesting for people in this sector to seriously consider the long term viability of this tilapia industry. Possible remedies, two scenarios may be considered as moving to another industry or relocation in developing countries where the production cost is low;
2. The tilapia grow-out farms that operated under large scale in the southern and middle Taiwan should be encouraged or supported in their activity due to their economic efficiency;

3. The tilapia grow-out farms that operated under small scale should form a cooperative in order to reach an efficient size for their short term subsistence;

4. To implement a program that can incite the farmers to record production data. This would help researchers in acquiring updated quantitative data and make it easier to conduct research;

5. Finally the sample size of the study was small due to incomplete data and outliers. In the future we suggest the use of large sample size and updated data for this type of research;

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Table 1. Top 10 Global Producers of Tilapia Farming in 2012

Countries	Production in metric tonnes
China	1,552,733
Egypt	768,752
Indonesia	717,831
Brazil	286,460
Philippines	260,536
Thailand	153,357
Bangladesh	123,712
Vietnam	100,000
Taiwan ROC	73,334
Colombia	52,688

Source: FAO, 2014, retrieved by Tacon, 2014

Table 2. Top 10 Aquaculture Species in Taiwan

Rank	Species	Production (MT)
1	Tilapia	76,087
2	Milkfish	53,245
3	Hard clam	35,655
4	Oyster	28,199
5	Japanese eel	24,822
6	Groupers	17,234
7	Asian clam	14,574
8	Pacific white shrimp	10,093
9	Seaweeds (Gracilaria)	9,382
10	Barramundi	8,858

Source: Liao and Leano, 2010, reported by Macenat 2011

Table 3. Distribution of the Sample Size of the Study based on Geographical Location and Production Scale

Production Scale / Location	Less than 1 hectare (Small scale)	Between 1 and 6.5 hectare (large scale)	Total
North	4	4	8
Middle	3	4	7
South	3	10	13
Total	10	18	28

Source: Secondary data from aquatic nutrition laboratory collected in 2008

Table 4. Introduced Tilapia Species to Taiwan

Tilapia Spp	Year of Introduction	Country of Origin	Characteristics
Mozambique Tilapia	1946	Singapore	Adaptability to brackish and salty waters, low growth rate and intolerance to low temperatures
Red Belly Tilapia	1963	South Africa	High resistance to low temperatures (5-6^{o}C)
Nile Tilapia	1966	Japan	Bigger size, relatively high resistance to low temperatures, excellent results for hybridization
Blue Tilapia	1974	Israel	High tolerance to salinity, good results for hybridization
Red Tilapia	1968	Unknown	Body shape and size similar to Nile Tilapia
Red Breast Tilapia	1981	South Africa	Slow growth rate and small size, orange skin with black spots
Tilapia Hornorum	1981	Costa Rica	Slow growth rate, small size, intolerable to low temperatures good results for hybridizing
Tilapia Spilurus	1997	Saudi Arabia	High tolerance to salinity

Source: Cardona, 2007 cited by Dahani, 2011

Table 5. Exports Tilapia: China

	................Jan-Mar................					
	2008	2009	2010	2011	2012	2013
			(1,000 tonnes)			
frozen whole	2.3	3.5	11.7	24.4	21.2	23.1
frozen fillets	1.3	12.7	35.4	32.7	33.6	30.7
other tilapia	41	30.4	12	14.7	11.7	13.3
Total	**44.5**	**46.7**	**59.1**	**72**	**66.5**	**67.1**
			(million USD)			
frozen whole	3	5.2	17.3	45.8	40.3	48.3
frozen fillets	4	50.4	119.9	141.4	139.1	125.5
preserved	97.2	92.1	27.5	51.6	45.8	48.5
Total	**104.2**	**147.8**	**164.9**	**238.8**	**225.2**	**222.3**

Source: China Customs cited by Globefish, 2013

Table 6. Imports Whole Frozen Tilapia: USA

	................Jan-Mar................					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
	(1,000 tonnes)					
China	7.7	5.2	5.6	5.9	6.6	5.3
Taiwan ROC	3.8	4	3	3.3	2.8	3.5
Thailand	0	0.5	0.3	0.1	0.2	0.1
Others	1.2	0.2	0.1	0.2	0.4	0.2
Total	**12.7**	**9.9**	**9**	**9.5**	**10**	**9.1**

Source: NMFS cited by Globefish, 2013

Table 7. Imports Frozen Tilapia Fillets: USA

	................Jan-Mar................					
	2008	**2009**	**2010**	**2011**	**2012**	**2013**
	(1,000 tonnes)					
China	23.2	24.4	29.6	31.5	36.1	32.8
Indonesia	2.3	2.3	2	2.2	2.9	2.4
Taiwan ROC	0.6	0.6	0.4	0.5	0.4	0.3
Thailand	0	0	0.3	0.3	0.5	0.3
Others	0.4	0.6	0.6	0.6	0.6	0.5
Total	**26.5**	**27.9**	**32.9**	**35.1**	**40.5**	**36.3**

Source: NMFS cited by Globefish, 2013

Table 8. Imports Fresh Tilapia Fillets: USA

	................Jan-Mar................					
	2008	2009	2010	2011	2012	2013
	(1,000 tonnes)					
Honduras	1.5	1.5	1.6	1.9	0.5	2.3
Ecuator	2.6	2.6	2.5	2.3	1.5	1.9
Costa Rica	2.2	1.6	1.7	1.7	0	1.6
Taiwan ROC	**0.1**	**0**	**0**	**0.1**	**0.1**	**0.5**
El Salvador	0.1	0	0.1	0.1	0	0.1
Others	1.1	0.7	0.8	0.6	0.5	0.8
Total	**7.6**	**6.4**	**6.7**	**6.7**	**2.6**	**7.2**

Source: NMFS cited by Globefish, 2013

Table 9. Imports Tilapia (by products form): USA

	................Jan-Mar................					
	2008	2009	2010	2011	2012	2013
	(1,000 tonnes)					
Whole frozen	12.7	9.9	9	9.5	10	9.1
Frozen fillets	26.5	27.9	32.9	35.1	40.5	36.3
Fresh fillets	7.6	6.4	6.7	6.7	2.6	7.2
Total	**46.8**	**44.2**	**48.6**	**51.3**	**53.1**	**52.6**

Source: NMFS cited by Globefish, 2013

Table 10. Input Intensities of 28 Retained Tilapia Grow-out Farming

[a] Input Intensity	Statistics (n=28)			
	Maximum[b]	Minimum[b]	Mean[b]	Standard[b] Deviation
Fry	65.000	0.857	13.842	18.789
Feed-fertilizer	187.500	6.363	58.102	47.286
Water-electricity-fuel	22.500	0.312	6.498	6.413
Labor	52.500	0.435	6.434	11.809
Fixed cost	37.200	0.644	5.844	9.106

[a] Input intensity is obtained by dividing the input cost by the total size in hectare (New Taiwan Dollar/ha).
[b] The currency is 100,000 New Taiwan Dollar per hectare; with 1 USD = 30 NTD

Table 11. Varied Profitabilities of 28 Retained Tilapia Grow-out Farming

[a] Varied Profitabilities	Statistics (n=28)			
	Maximum[b]	Minimum[b]	Mean[b]	Standard[b] Deviation
Fry	47.400	-8.605	6.298	10.319
Feed-fertilizer	4.176	-0.422	0.923	0.982
Water-electricity-fuel	41.200	-4.303	10.197	10.733
Labor	85.500	-11.952	12.559	17.306
Fixed cost	151.341	-43.028	14.267	30.180

[a] Varied profitabilities are defined as net revenue divided by different input intensity. Additionally, total cost subtracted from total revenue gives net revenue
[b] The currency is New Taiwan Dollar per hectare ; with 1 USD = 30 NTD

Table 12. Two-way MANOVA of Input Intensity Variables based on Geographical Location and Production Scale

Number of factors	Statistical criteria	Value	*F*-value	*Pr* > *F*
Production scale (PS)	Wilks' Lambda	0.1598	18.93	<.0001
	Pillai's Trace	0.8401	18.93	<.0001
	Hotelling-Lawley Trace	5.2569	18.93	<.0001
	Roy's Greatest Root	5.2569	18.93	<.0001
Location (L)	Wilks' Lambda	0.0431	13.73	<.0001
	Pillai's Trace	1.4429	9.84	<.0001
	Hotelling-Lawley Trace	10.9135	19.02	<.0001
	Roy's Greatest Root	9.7589	37.08	<.0001
Interaction of PS and L	Wilks' Lambda	0.1073	7.39	<.0001
	Pillai's Trace	1.1724	5.38	<.0001
	Hotelling-Lawley Trace	5.7073	9.95	<.0001
	Roy's Greatest Root	5.2068	19.79	<.0001

Table 13. Mean's Comparison of Input Intensity Variables between two Production Scales and three Geographical Locations of Tilapia Grow-out Farming

Production scale and location	Number of farms (n)	Fry intensity[1]		Feed-fertilizer intensity[1]		Water-electricity-fuel intensity[1]		Labor intensity[1]		Fixed cost intensity[1]	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Small scale	10	28.282[a]	25.636	97.316[a]	49.476	11.987[a]	5.536	14.183[a]	17.613	12.660[a]	12.682
Large scale	18	5.819[b]	4.686	36.316[b]	29.123	3.448[b]	4.639	2.130[b]	1.523	2.0572 [b]	2.005
North	8	32.969[a]	25.728	95.287[a]	58.019	9.741[a]	9.333	16.809[a]	18.932	12.262[a]	13.507
Middle	7	11.647[b]	8.826	80.518[a]	18.119	9.074[a]	3.756	4.068[b]	1.129	3.443[b]	2.843
South	13	3.253[c]	1.028	23.148[b]	19.092	3.166[c]	3.475	1.324[b]	0.875	3.187[b]	6.133

[1] The currency is 100,000 New Taiwan Dollar per hectare (1 USD = 30 NTD) and then the means with the same letter (a, b and c) indicate they are not significantly different at P= 0.05

Table 14. Mean's Comparison of Input Intensity Variables between Six Groups of Tilapia Grow-out Farming

Production scale with location	Number of farms (n)	Fry intensity[1]		Feed-fertilizer intensity[1]		Water-electricity-Fuel intensity[1]		Labor intensity[1]		Fixed cost intensity[1]	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Small-North	4	56.250[a]	9.242	143.750[a]	38.864	17.187[a]	5.241	30.937[a]	17.421	23.198[a]	10.324
Small-Middle	3	14.799[b]	11.806	81.386[b]	26.268	9.301[b]	0.715	3.587[b]	1.594	2.418[b]	1.953
Small-South	3	4.475[c]	1.628	51.335[c]	13.984	7.737[b]	2.052	2.438[b]	1.239	8.850[b]	12.606
Large-North	4	9.688[bc]	3.712	46.824[c]	9.003	0.960[c]	0.463	2.681[b]	0.706	1.325[b]	0.431
Large-Middle	4	9.284[bc]	6.745	79.868[c]	13.974	10.071[b]	5.248	4.428[b]	0.670	4.211[b]	3.434
Large-South	10	2.886[c]	0.417	14.692[d]	9.913	1.794[c]	2.471	0.990[b]	0.376	1.488[b]	0.971

[1] The currency is 100,000 New Taiwan Dollar per hectare (1 USD = 30 NTD) and then the means with the same letter (a, b and c) indicate they are not significantly different at P= 0.05

Table 15. Two-way MANOVA of Varied Profitability Variables based on Geographical Location and Production Scale

Number of factors	Statistical criteria	Value	F-value	*Pr > F*
Production scale (PS)	Wilks' Lambda	0.6889	1.63	0.2040
	Pillai's Trace	0.3110	1.63	0.2040
	Hotelling-Lawley Trace	0.4515	1.63	0.2040
	Roy's Greatest Root	0.4515	1.63	0.2040
Location (L)	Wilks' Lambda	0.3672	2.34	0.0302
	Pillai's Trace	0.7449	2.26	0.0349
	Hotelling-Lawley Trace	1.4176	2.47	0.0332
	Roy's Greatest Root	1.1526	4.38	0.0080
Interaction of PS and L	Wilks' Lambda	0.4195	1.96	0.0687
	Pillai's Trace	0.6182	1.70	0.1165
	Hotelling-Lawley Trace	1.2932	2.25	0.0494
	Roy's Greatest Root	1.2192	4.63	0.0062

Table 16. Mean's Comparison of Varied Profitability Variables between three Geographical Locations of Tilapia Grow-out Farming

Production scale and location	Number of farms (n)	Fry profitability[1]		Feed-fertilizer profitability[1]		Water-electricity-fuel profitability[1]		Labor profitability[1]		Fixed cost profitability[1]	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
North	8	0.994[b]	0.685	0.354[b]	0.312	4.526[b]	1.443	2.495[b]	1.948	3.50[a]	1.908
Middle	7	12.882[a]	17.747	0.591[b]	0.606	6.361[b]	7.461	11.474[ab]	9.288	32.44[a]	52.969
South	13	6.019[ab]	6.141	1.451[a]	1.161	15.753[a]	12.910	19.336[a]	22.595	3.50[a]	19.065

[1] The currency is New Taiwan Dollar (1 USD = 30 NTD); the means with the same letter (a, b and c) indicate they are not significantly different at P= 0.05

Table 17. Mean's Comparison of Varied Profitability Variables between Six Groups of Tilapia Grow-out Farming

Production scale with location	Number of farms (n)	Fry profitability[1]		Feed-Fertilizer profitability[1]		Water-electricity-fuel profitability[1]		Labor profitability[1]		Fixed cost profitability[1]	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Small-North	4	1.606[a]	0.229	0.640[ab]	0.093	5.480[b]	1.175	3.710[ab]	2.159	4.530[ab]	2.303
Small-Middle	6	9.681[a]	14.597	0.379[b]	0.133	3.240[b]	1.094	8.960[ab]	3.676	16.820[ab]	8.456
Small-South	3	1.675[a]	11.780	0.320[b]	1.029	1.203[b]	6.570	-0.440[b]	13.992	-7.010[b]	33.156
Large-North	5	0.381[a]	0.207	0.068[b]	0.014	3.572[b]	1.024	1.280[ab]	0.532	2.46[ab]	0.585
Large-Middle	3	15.283[a]	21.679	0.750[ab]	0.803	8.701[ab]	9.670	13.36[ab]	12.347	44.16[a]	71.670
Large-South	4	7.322[a]	3.357	1.790[a]	1.005	20.118[a]	10.995	25.27[a]	21.628	16.55[ab]	9.905

[1] The currency is New Taiwan Dollar (1 USD = 30 NTD); the means with the same letter (a, b and c) indicate they are not significantly different at P= 0.05

Table 18. A Correlation Matrix of Input Intensity Variables

Input intensity[a]	Fry	Feed-fertilizer	Water-electricity-fuel	Labor	Fixed cost
Fry	1.0000	0.8182	0.7743	0.8676	0.7403
Feed-fertilizer	0.8182	1.0000	0.8504	0.7934	0.6498
Water-electricity-fuel	0.7743	0.8504	1.0000	0.7459	0.7280
Labor	0.8676	0.7934	0.7459	1.0000	0.8068
Fixed cost	0.7403	0.6498	0.7280	0.8068	1.0000

[a] Input intensity is obtained by dividing the input cost by the total size in hectare (NTD /ha)

Table 19. The Eigenvalues[a] and Eigenvectors[b] Computed from a Correlation Matrix of Input Intensity Variables

Principal component	Eigenvalue	Account for in percentage (%)	Eigenvector, coefficient of				
			Fry (FR)	Feed-fertilizer (FF)	Water-electricity-fuel (WEF)	Labor (LR)	Fixed cost (FC)
I_1	4.1126	82.25	0.4576	0.4478	0.4456	0.4587	0.4254
I_2	0.3899	7.80	-0.0167	-0.5494	-0.3686	0.2584	0.7036
I_3	0.2656	5.31	-0.5160	-0.0474	0.6084	-0.4245	0.4254
I_4	0.1318	2.64	-0.6971	0.4847	-0.2793	0.4453	0.0521
I_5	0.0999	2.00	0.1947	0.5103	-0.4661	-0.5867	0.3743

[a] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variances of 5.0000. Thus, the first principal component (I_1) accounts for (4.1126/5.0000)100% = 82.25 %, I_2 accounts for (0.3899/5.0000)100% = 7.80 %, etc.

[b] The eigenvectors represent the coefficients of the standardized variables (input intensities), e.g., $I_1 = 0.4576FR + 0.4478FF + 0.4456WEF + 0.4587LR + 0.4254FC$

Table 20. A Correlation Matrix of Varied Profitability Variables

Varied profitability[a]	Fry	Feed-fertilizer	Water-electricity-fuel	Labor	Fixed cost
Fry	1.0000	0.1692	0.1705	0.3281	0.2415
Feed-fertilizer	0.1692	1.0000	0.6472	0.4760	0.3416
Water-electricity-fuel	0.1705	0.6472	1.0000	0.3177	0.3251
Labor	0.3281	0.4760	0.3177	1.0000	0.5124
Fixed cost	0.2415	0.3416	0.3251	0.5124	1.0000

[a] Varied profitabilities are defined as net revenue divided by different input intensity. Additionally, total cost subtracted from total revenue gives net revenue.

Table 21. The Eigenvalues[a] and Eigenvectors[b] Computed from a Correlation Matrix of Varied Profitability Variables

Principal component	Eigenvalue	Account for in percentage (%)	Eigenvector, coefficient of				
			Fry (FR)	Feed-fertilizer (FF)	Water-electricity-fuel (WEF)	Labor (LR)	Fixed cost (FC)
P_1	2.4565	49.13	0.2975	0.5061	0.4659	0.4904	0.4445
P_2	0.9847	19.69	0.6828	-0.4163	-0.4854	0.2564	0.2428
P_3	0.7434	14.87	0.6483	0.1592	0.3115	-0.3079	-0.6020
P_4	0.5092	10.19	0.1271	-0.2657	0.3485	-0.6674	0.5884
P_5	0.3060	6.12	0.0933	0.6888	-0.5733	-0.3916	0.1862

[a] The eigenvalue for a principal component indicates the variance that it accounts for out of the total variances of 5.0000. Thus, the first principal component (P_1) accounts for (2.4565/5.0000)100% = 49.13 %, P_2 accounts for (0.9847/5.0000)100% = 19.69 %, etc.

[b] The eigenvectors represent the coefficients of the standardized variables (varied profitabilities), for instance, $P_1 = 0.2975FR + 0.5061FF + 0.4659WEF + 0.4904LR + 0.4445FC$

Table 22. A Matrix of Mahalanobis[a] Distance of Input Intensity Variables between Six Groups of Tilapia Grow-out Farming

	A(small scale-north)	B(small scale-middle	C(small scale-south)
A (small scale- north)	0	26.06793	36.57859
	(1.0000)	(<.0001)	(<.0001)
B (small scale- middle)	26.06793	0	1.74922
	(<.0001)	(1.0000)	(0.1745)
C(small scale- south)	36.57859	1.74922	0
	(<.0001)	(0.1745)	(1.0000)
D(large scale- north)	36.19381	2.78956	2.81567
	(<.0001)	(0.0490)	(0.0476)
E(large scale- middle)	37.13772	0.49222	0.96937
	(<.0001)	(0.7778)	(0.4624)
F(large scale- south)	76.98691	8.06088	3.53217
	(<.0001)	(0.0004)	(0.0212)

[a] Mahalanobis distance was expressed considering the five input intensity variables including fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost as a whole, and calculated as;

$D^2ij = (\overline{x}_i-\overline{x}_j)' C^{-1}(\overline{x}_i-\overline{x}_j)$,

where D^2ij is the Mahalanobis distance between group i and group j, xi is a mean vector of the ith group with dimensions 5x1 (Table 5), C^{-1} is a unique inverse of variance-covariance matrix C with dimensions 5x5 (Table 5). For instance, the Mahalanobis distance between A (small scale-north) and C (small scale-south) is 36.57859 and the probability (p) of distances greater than 36.57859 is < 0.0001 in parenthesis. Thus, this implies that these two groups were significantly „distant" (different) to each other as compared to their corresponding means in fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost inputs as whole.

Table 22. A Matrix of Mahalanobis[a] Distance of Input Intensity Variables between Six Groups of Tilapia Grow-out Farming (Continuation)

	D(large scale-north)	E(large scale-middle)	F(large scale-south)
A (small scale - north)	36.19381	37.13772	76.98691
	(<.0001)	(<.0001)	(<.0001)
B (small scale - middle)	2.78956	0.49222	8.06088
	(0.0490)	(0.7778)	(0.0004)
C(small scale - south)	2.81567	0.96937	3.53217
	(0.0476)	(0.4624)	(0.0212)
D(large scale - north)	0	4.05554	3.91880
	(1.0000)	(0.0122)	(0.0140)
E(large scale - middle)	4.05554	0	8.41400
	(0.0122)	(1.0000)	(0.0003)
F(large scale - south)	3.91880	8.41400	0
	(0.0140)	(0.0003)	(1.0000)

[a]Mahalanobis distance was expressed considering the five input intensity variables including fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost as a whole, and calculated as;

$D^2ij = (\bar{x}_i-\bar{x}_j)' C^{-1}(\bar{x}_i-\bar{x}_j)$,

where D^2_{ij} is the Mahalanobis distance between group i and group j, xi is a mean vector of the $_i$th group with dimensions 5x1 (Table 5), C^{-1} is a unique inverse of variance-covariance matrix C with dimensions 5x5 (Table 5). For instance, the Mahalanobis distance between A (small scale-north) and F (large scale-south) is 76.98691and the probability (p) of distances greater than 76.98691 is < 0.0001 in parenthesis. Thus, this implies that these two categories were significantly „distant‟ (different) to each other as compared to their corresponding means in fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost inputs as whole.

Table 23. A Matrix of Mahalanobis[a] Distance of Varied Profitability Variables between Six Groups of Tilapia Grow-out Farming

	A(small scale-north)	B(small scale-middle	C(small scale-south)
A (small scale- north)	0	0.43374	0.14272
	(1.0000)	(0.8192)	(0.9797)
B (small scale- middle)	0.43374	0	0.34105
	(0.8192)	(1.0000)	(0.8813)
C(small scale- south)	0.14272	0.34105	0
	(0.9797)	(0.8813)	(1.0000)
D(large scale- north)	0.22735	0.34776	0.12485
	(0.9457)	(0.8770)	(0.9849)
E(large scale- middle)	1.45173	0.38054	1.42583
	(0.2540)	(0.8555)	(0.2625)
F(large scale- south)	5.44802	6.50272	6.15363
	(0.0032)	(0.0013)	(0.0017)

[a] Mahalanobis distance was expressed considering the five input intensity variables including fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost as a whole, and calculated as;

$D^2ij = (\bar{x}_i-\bar{x}_j)' C^{-1}(\bar{x}_i-\bar{x}_j)$,

where D^2ij is the Mahalanobis distance between group i and group j, xi is a mean vector of the ith group with dimensions 5x1 (Table 5), C^{-1} is a unique inverse of variance-covariance matrix C with dimensions 5x5 (Table 5). For instance, the Mahalanobis distance between F (large scale-south) and B (small scale-middle) is 6.50272 and the probability (p) of distances greater than 6.50272 is 0.0013 in parenthesis. Thus, this implies that these two categories were significantly “distant” (different) to each other as compared to their corresponding means in fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost inputs as whole.

Table 23. A Matrix of Mahalanobis[a] Distance of Varied Profitability Variables between Six Groups of Tilapia Grow-out Farming (Continuation)

	D(large scale-north)	E(large scale-middle)	F(large scale-south)
A (small scale - north)	0.22735	1.45173	5.44802
	(0.9457)	(0.2540)	(0.0032)
B (small scale - middle)	0.34776	0.38054	6.50272
	(0.8770)	(0.8555)	(0.0013)
C(small scale - south)	0.12485	1.42583	6.15363
	(0.9849)	(0.2625)	(0.0017)
D(large scale - north)	0	1.44002	7.69230
	(1.0000)	(0.2578)	(0.0005)
E(large scale - middle)	1.44002	0	8.91118
	(0.2578)	(1.0000)	(0.0002)
F(large scale - south)	7.69230	8.91118	0
	(0.0005)	(0.0002)	(1.0000)

[a]Mahalanobis distance was expressed considering the five input intensity variables including fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost as a whole, and calculated as;

$D^2ij = (\overline{x}_i-\overline{x}_j)' C^{-1}(\overline{x}_i-\overline{x}_j)$,

where D2ij is the Mahalanobis distance between group i and group j, xi is a mean vector of the ith group with dimensions 5x1 (Table 5), C-1 is a unique inverse of variance-covariance matrix C with dimensions 5x5 (Table 5). For instance, the Mahalanobis distance between F (large scale-south) and E (large scale-middle) is 8.91118 and the probability (p) of distances greater than 8.91118 is 0.0002 in parenthesis. Thus, this implies that these two categories were significantly „distant" (different) to each other as compared to their corresponding means in fry, feed-fertilizer, water-electricity-fuel, labor and fixed cost inputs as whole.

Table 24. Eigenvalue and Proportion for Input Intensity Variables

Canonical correlation	Eigenvalue	Difference	Proportion	Cumulative	Approximate F value	Pr > F
1 0.9780	22.0212	19.6550	0.8813	0.8813	7.40	<.0001
2 0.8384	2.3662	1.9297	0.0947	0.9760	2.79	0.0022
3 0.5512	0.4365	0.2914	0.0175	0.9934	1.28	0.2705
4 0.3558	0.1450	0.1260	0.0058	0.9992	0.84	0.5066
5 0.1365	0.0190		0.0008	1.0000	0.42	0.5247

Table 25. Raw Canonical Coefficients for Input Intensity Variables

Variable	Can1	Can2	Can3	Can4	Can5
Fry (FR)	0.0000170119	-0.0000086096	-0.0000028663	-0.0000034419	-0.0000082948
Feed fertilizer (FF)	0.0000039134	0.0000031059	-0.0000036096	0.0000025338	0.0000009094
Water-electricity-fuel (WEF)	-0.0000139776	0.0000267366	0.0000219903	-0.0000195809	-0.0000032739
Labor (LR)	-0.0000053422	-0.0000098700	0.0000046518	-0.0000071830	0.0000160083
Fixed cost (FC)	0.0000112819	-0.0000010462	0.0000063218	0.0000179129	-0.0000047342

Table 26. Eigenvalue and Proportion for Varied Profitability Variables

	Canonical correlation	Eigenvalue	Difference	Proportion	Cumulative	Approximate F value	Pr > F
1	0.9046	4.5079	3.9145	0.8734	0.8734	2.25	0.0044
2	0.6102	0.5933	0.5541	0.1150	0.9884	0.69	0.7945
3	0.1942	0.0392	0.0195	0.0076	0.9960	0.13	0.9985
4	0.1390	0.0197	0.0188	0.0038	0.9998	0.11	0.9790
5	0.0310	0.0010		0.0002	1.0000	0.02	0.8857

Table 27. Raw Canonical Coefficients for Varied Profitability Variables

Variable	Can1	Can2	Can3	Can4	Can5
Fry (FR)	-0.036364574	0.070271653	-0.037674326	-0.038268566	-0.050459363
Feed fertilizer (FF)	0.597175542	-0.018587631	-1.138166548	0.589382883	0.197408134
Water-electricity-fuel (WEF)	0.118135523	0.005075910	0.081592868	0.005227433	-0.059554098
Labor (LR)	0.073566863	-0.007917002	0.015980244	-0.045844733	0.034794633
Fixed cost (FC)	-0.036891780	0.026216819	0.009178872	0.019501381	0.011787579

Table 28. Analysis of Canonical Correlation between Input Intensity Variables and Biological Variables[a]

1st input intensity index	Coefficient of economic variables					Canonical correlation between P_1 and M_1	Approximated F	Pr>F
	Fry (FR)	Feed-fertilizer (FF)	Water-electricity-fuel (WEF)	Labor (LR)	Fixed cost (FC)			
P_1	0.5838	-0.1912	-0.1188	0.2249	0.5202	0.83	4.67	0.0002
1st manageability index	Coefficient of biological variables							
	Stocking density (SD)	Survival rate (SR)						
M_1	1.2387	0.8244						
2nd input intensity index	Coefficient of economic variables					Canonical correlation between P_2 and M_2	Approximated F	Pr>F
	Fry (FR)	Feed-fertilizer (FF)	Water-electricity-fuel (WEF)	Labor (FR)	Fixed cost (FC)			
P_2	-0.7601	-0.6914	1.0316	-0.6106	1.0807	0.52	2.06	0.1203
2nd manageability index	Coefficient of biological variables							
	Stocking density (SD)	Survival rate (SR)						
M_2	0.1096	-0.9310						

[a] Both indices of input intensity and manageability are linear combinations with corresponding variables. For instance, P_1= 0.5838FR - 0.1912FF - 0.1188WEF + 0.2249LR + 0.5202FC; M_1= 1.2387 SD + 0.8244 SR. All variables, including the indices, are in a standardized form with means of zero and standard deviations of unity.

Table 29. Correlations between Studied Variables and Canonical Variables

	Canonical variables			
	1st input intensity index (P_1)	1st manageability index (M_1)	2nd input intensity index (P_2)	2^{nd} manageability index (M_2)
Fry (FR)	0.9155	0.7614	-0.2567	-0.1341
Feed-fertilizer (FF)	0.7018	0.5837	-0.2182	-0.1140
Water-electricity-fuel (WEF)	0.7170	0.5963	0.1865	0.0974
Labor (LR)	0.9107	0.7574	-0.1771	-0.0925
Fixed cost (FC)	0.9230	0.7676	0.3271	0.1708
Stocking density (SD)	0.6226	0.7486	0.3463	0.6630
Survival rate (SR)	0.0733	0.0881	-0.5203	-0.9961

Table 30. Cobb-Douglas Production Function[a] Estimated by Relating[b] Unit Return to Input Intensity Variables

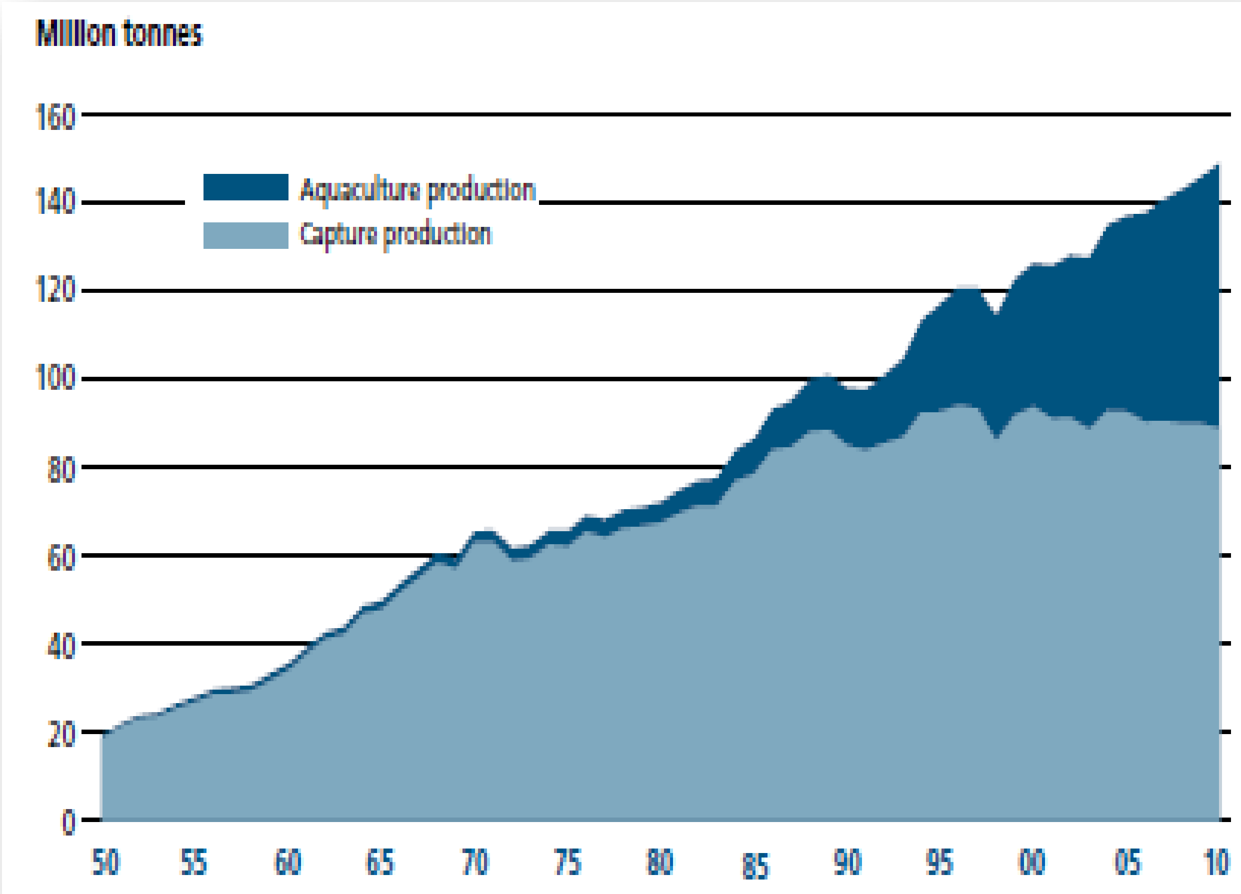
Parameter	Constant/Input intensity			
	Constant Log β0	Labor (LR) β1	Feed-fertilizer (FF) β2	Water-electricity-fuel (WEF) β3
Estimated parameter	2.2731	0.2847	0.2576	0.2134
Standard error	0.2781	0.0676	0.0943	0.0573
F value	66.800	17.700	7.4600	13.880
*P*r> *F*	<.0001	0.0003	0.0116	0.0011

[a] This function is determined as RE = 2.2731 $(LR)^{0.2847}$ $(FF)^{0.2576}$ $(WEF)^{0.2134}$; where RE is a unit return (production in new Taiwan dollar/hectare) and the input intensity variables (item cost in NTD/ha) [b] R^2 = 92.19% and adjusted R^2 = 91.21%.

Table 31. Hypotheses Testing Results

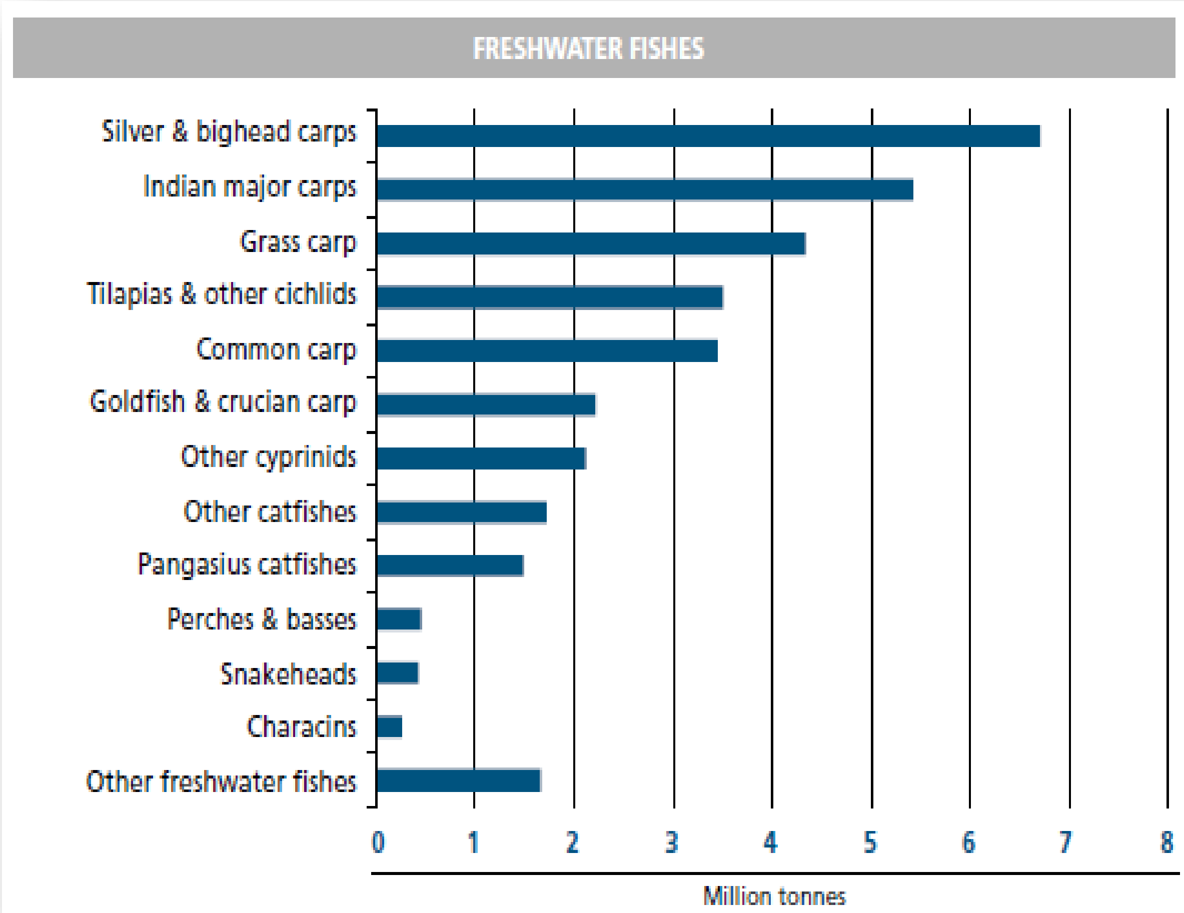
Hypotheses		Results
H1:	The geographical location, the production scale and their interaction have a significant effect on the input intensify variables.	Accepted
H2:	The geographical location, its interaction with the production scale have a significant effect on the varied profitability variables.	Accepted
H3:	The large scale in the southern and middle Taiwan is more profitable than the small scale in the northern Taiwan by referring to input intensity and varied profitability variables.	Accepted
H4:	The six (6) groups of tilapia grow-out farming are significantly distant from each other by referring to input intensity and varied profitability variables;	Rejected
H5:	In terms of management, the biological variables and economic variables are significant and strongly correlated.	Accepted
H6:	There exist diseconomies of scale in tilapia grow-out farming in Taiwan.	Accepted

Fig.1 World Capture Fisheries and Aquaculture Production



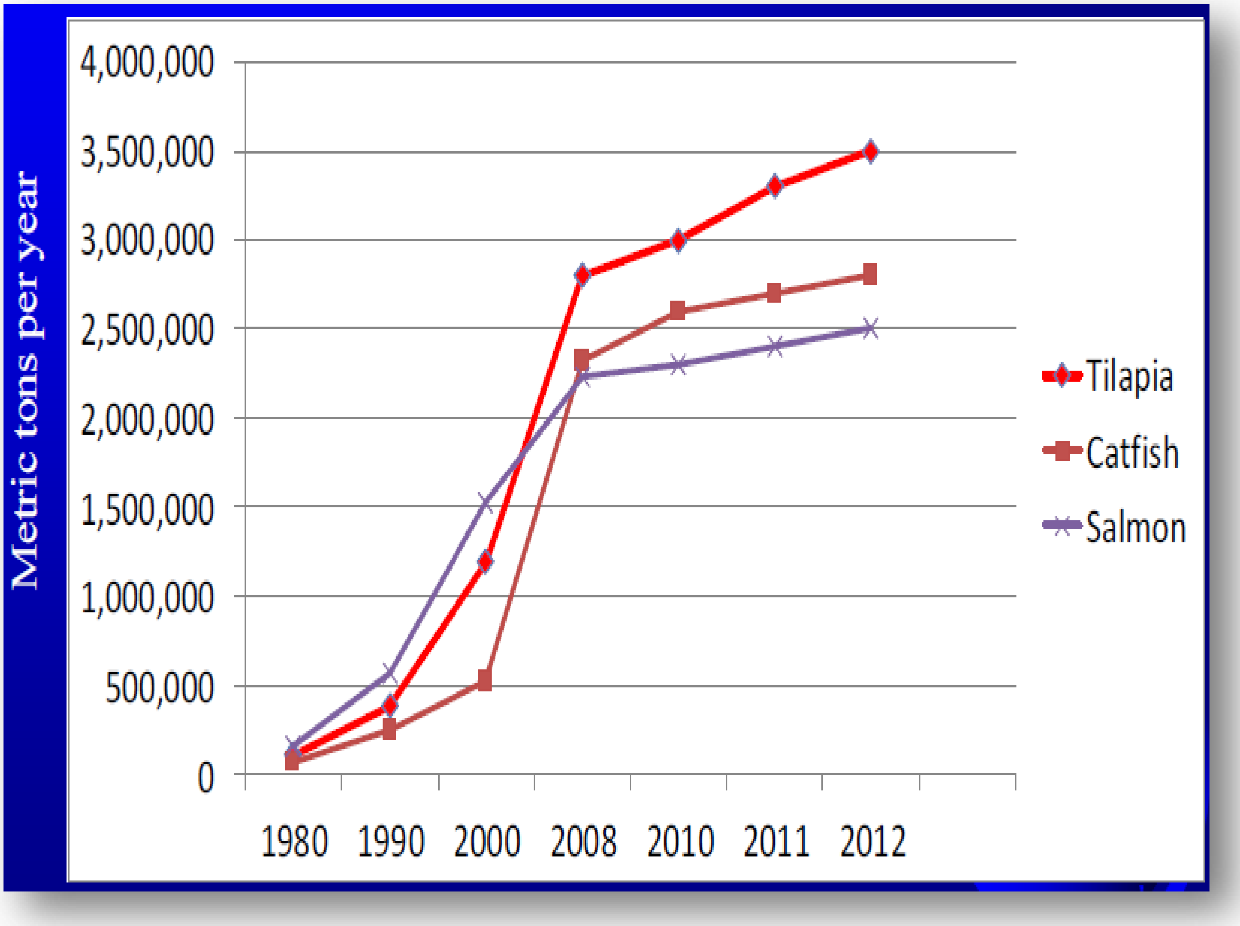
Source: FAO, 2012

Fig.2 Production of Major Species or Species Group from Aquaculture in 2010



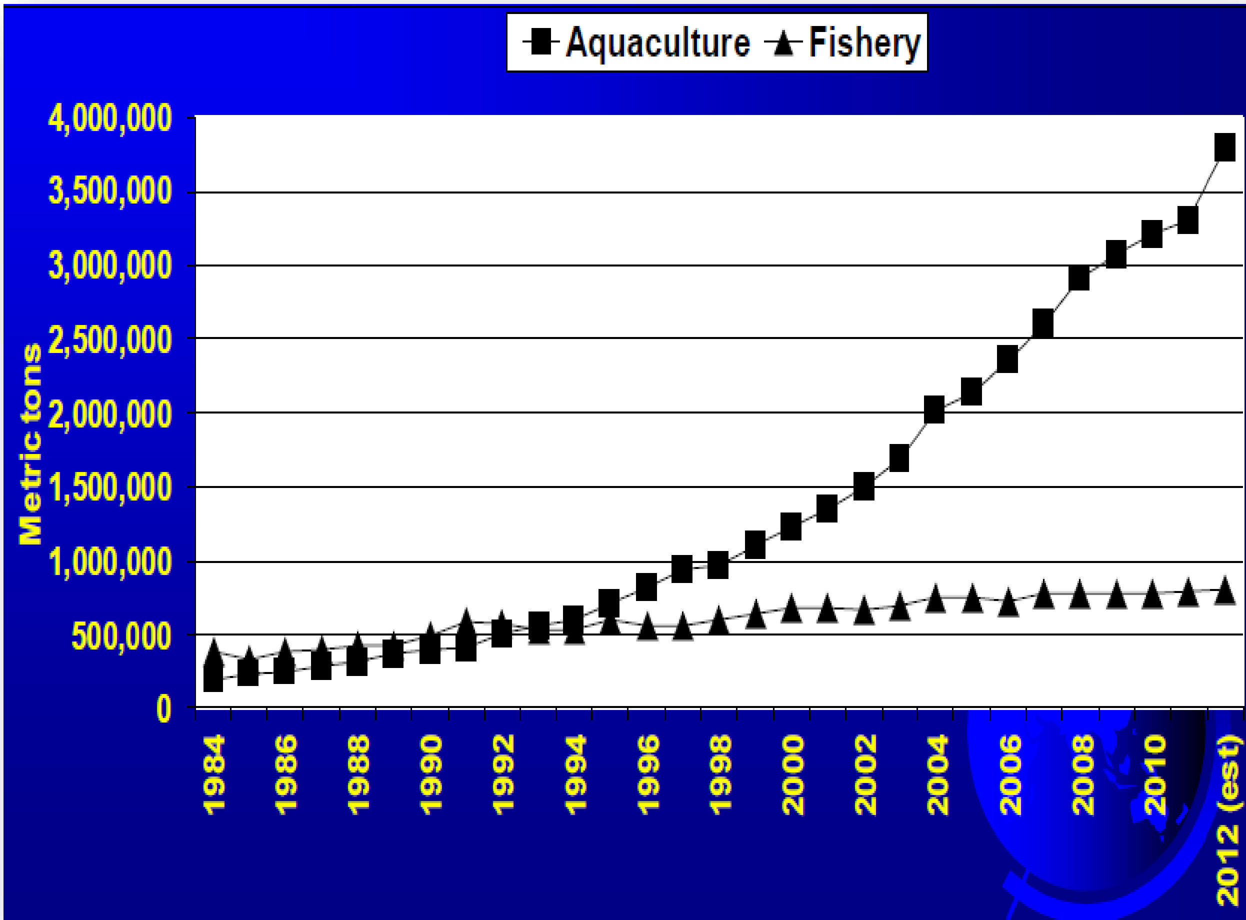
Source: FAO, 2012

Fig.3 Global Production of three Major Farmed Fishes



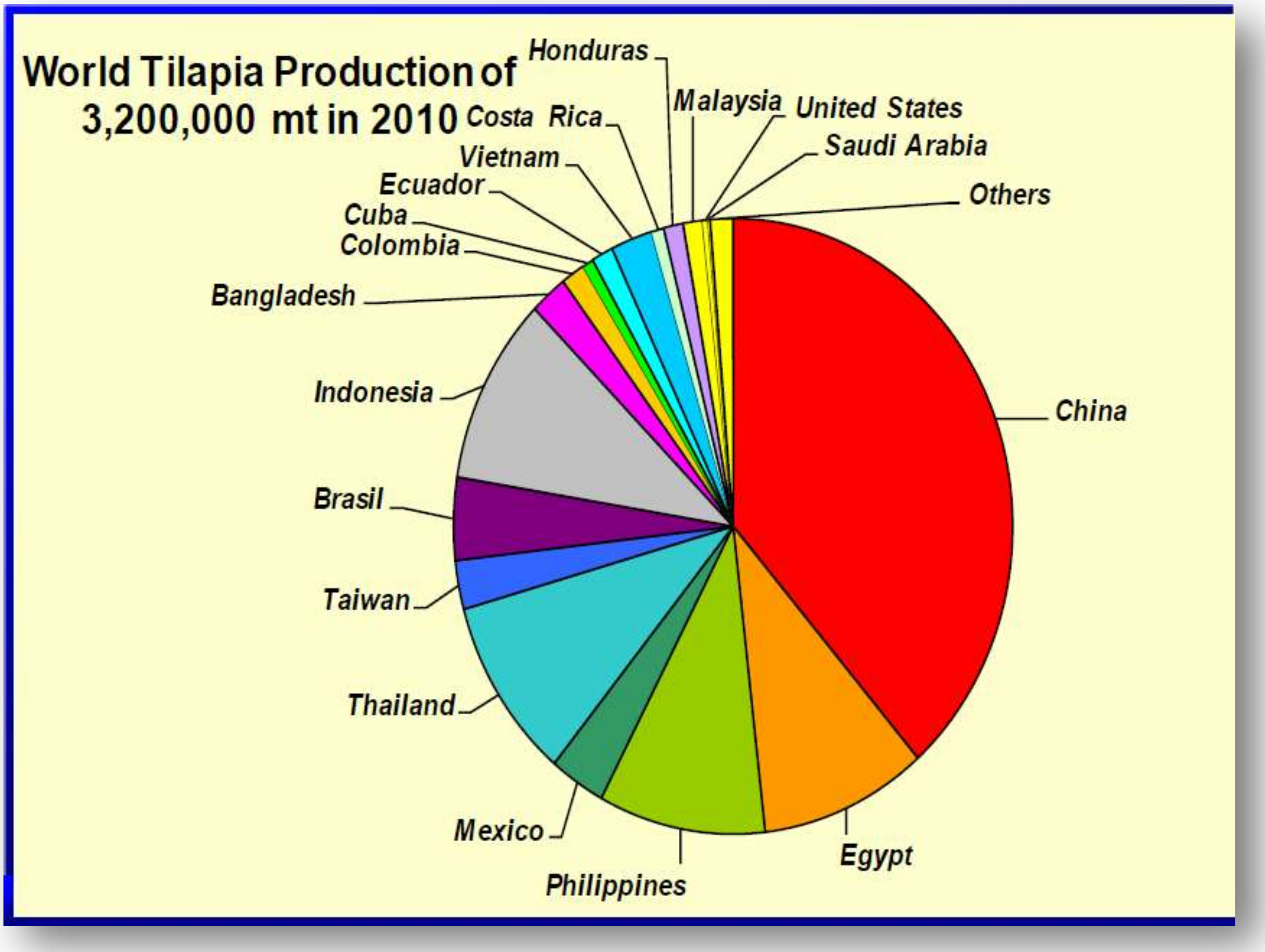
Source: Fitzsimmons, 2012

Fig.4 Global Production of Tilapia



Source: Kevin Fitzsimmons, 2012

Fig.5 World Tilapia Production per Country in 2010



Source: Kevin Fitzsimmons, 2011

Fig.6 Taiwan Map

Source: http://www.orientaltravel.com/Taiwan_map.htm

Fig.7 Oreochromis Niloticus (Linnaeus, 1758)

Source: FAO, 2005

Availableon: http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/en

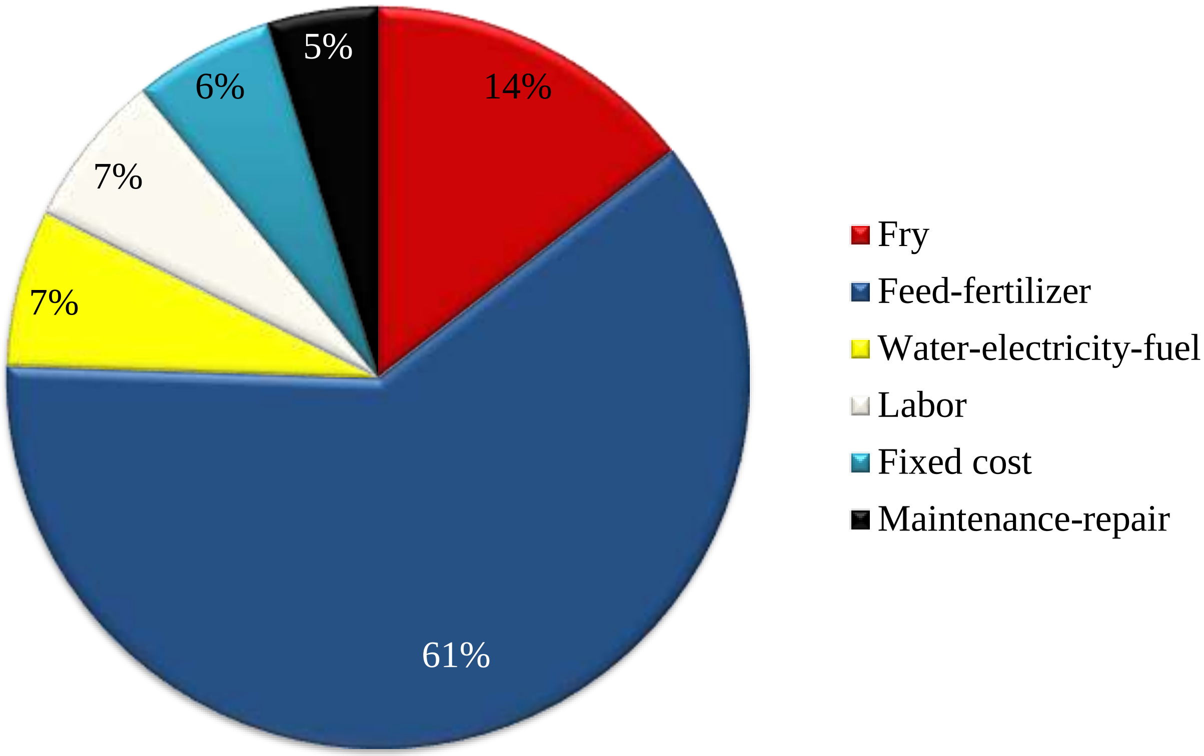


Fig.8 Distribution of Input Intensity Variables of 28 Tilapia Grow-out Farming

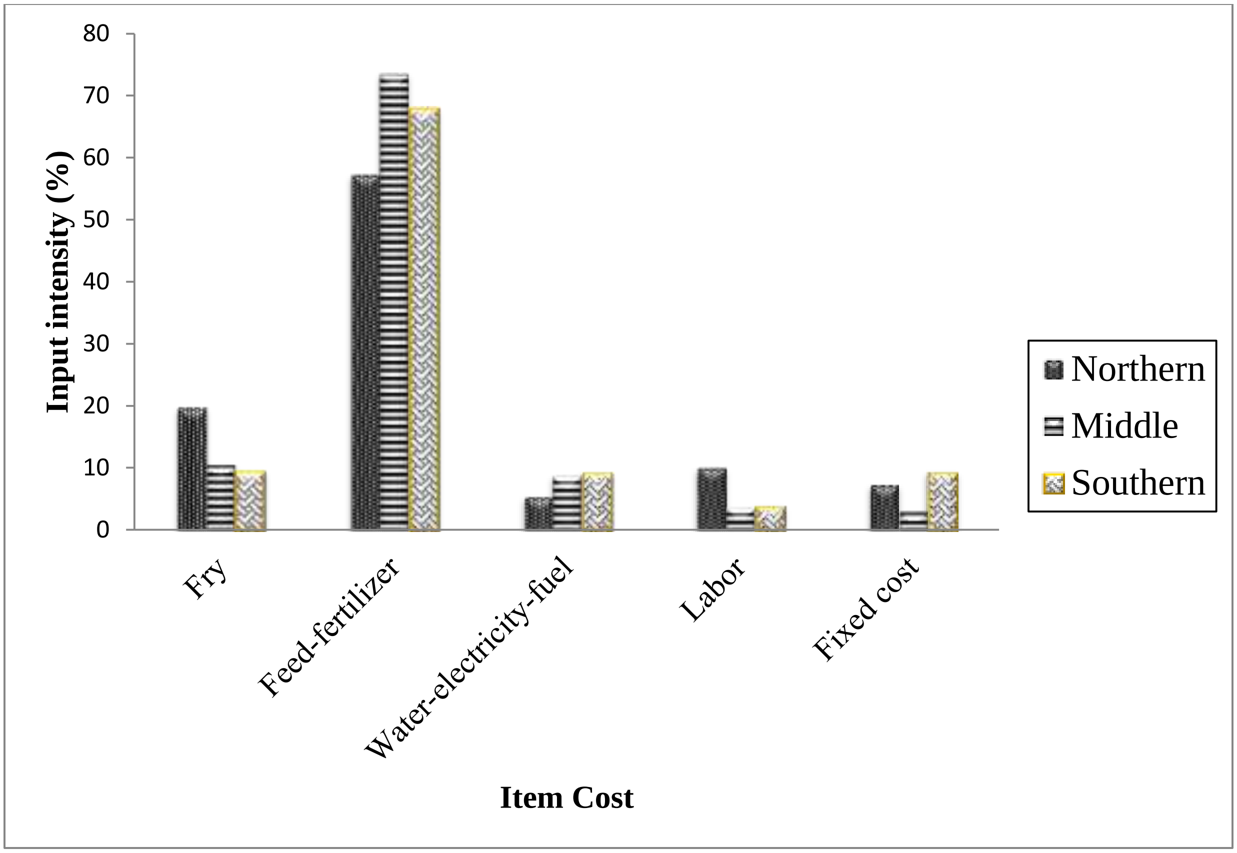


Fig.9 Input Intensity's Comparison between Three Geographical Locations: Northern, Middle and Southern Taiwan

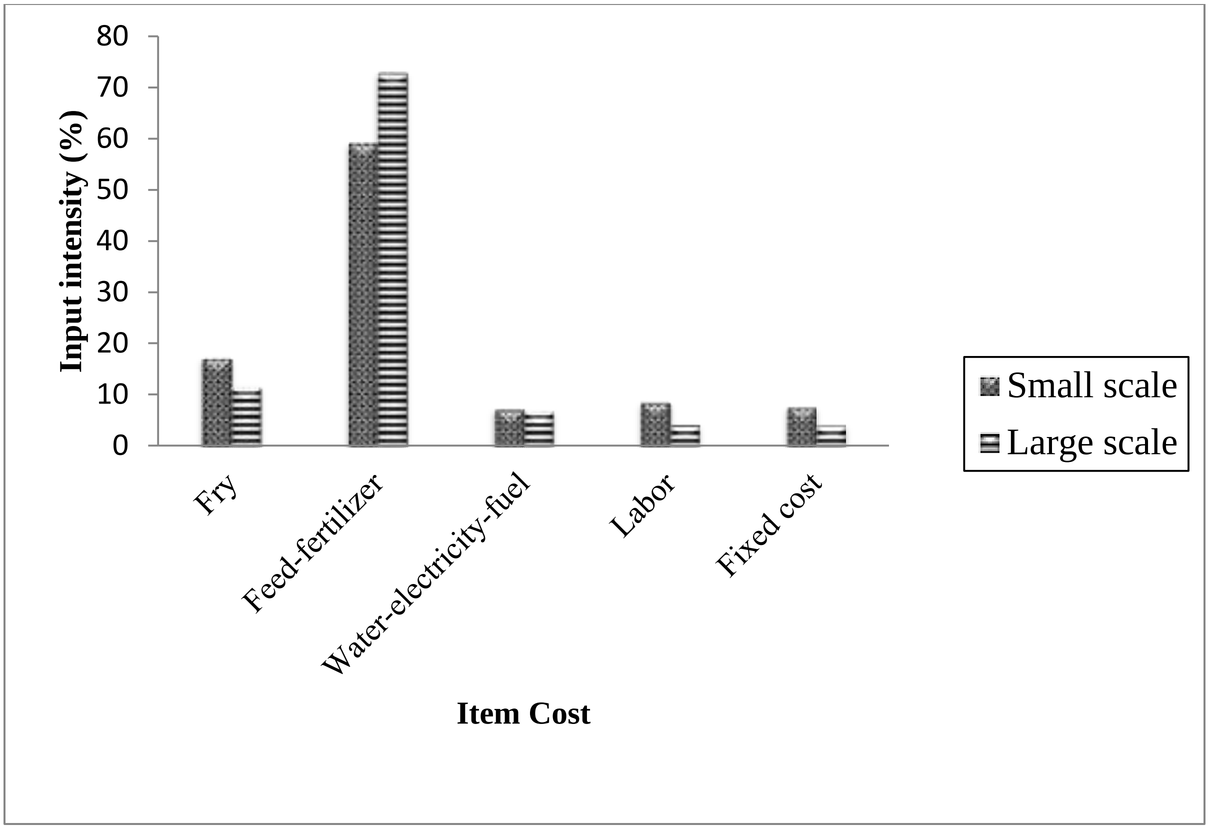
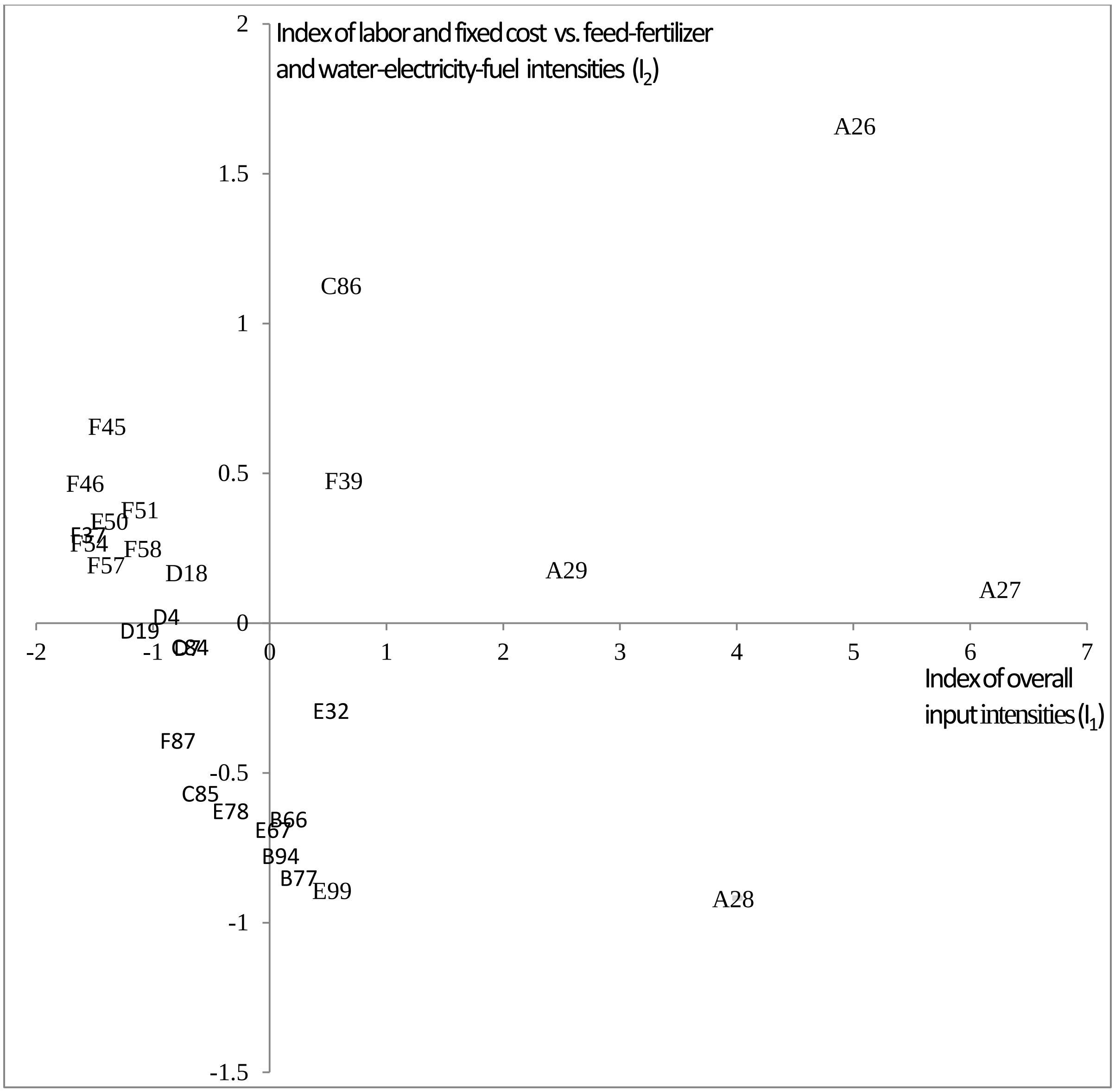


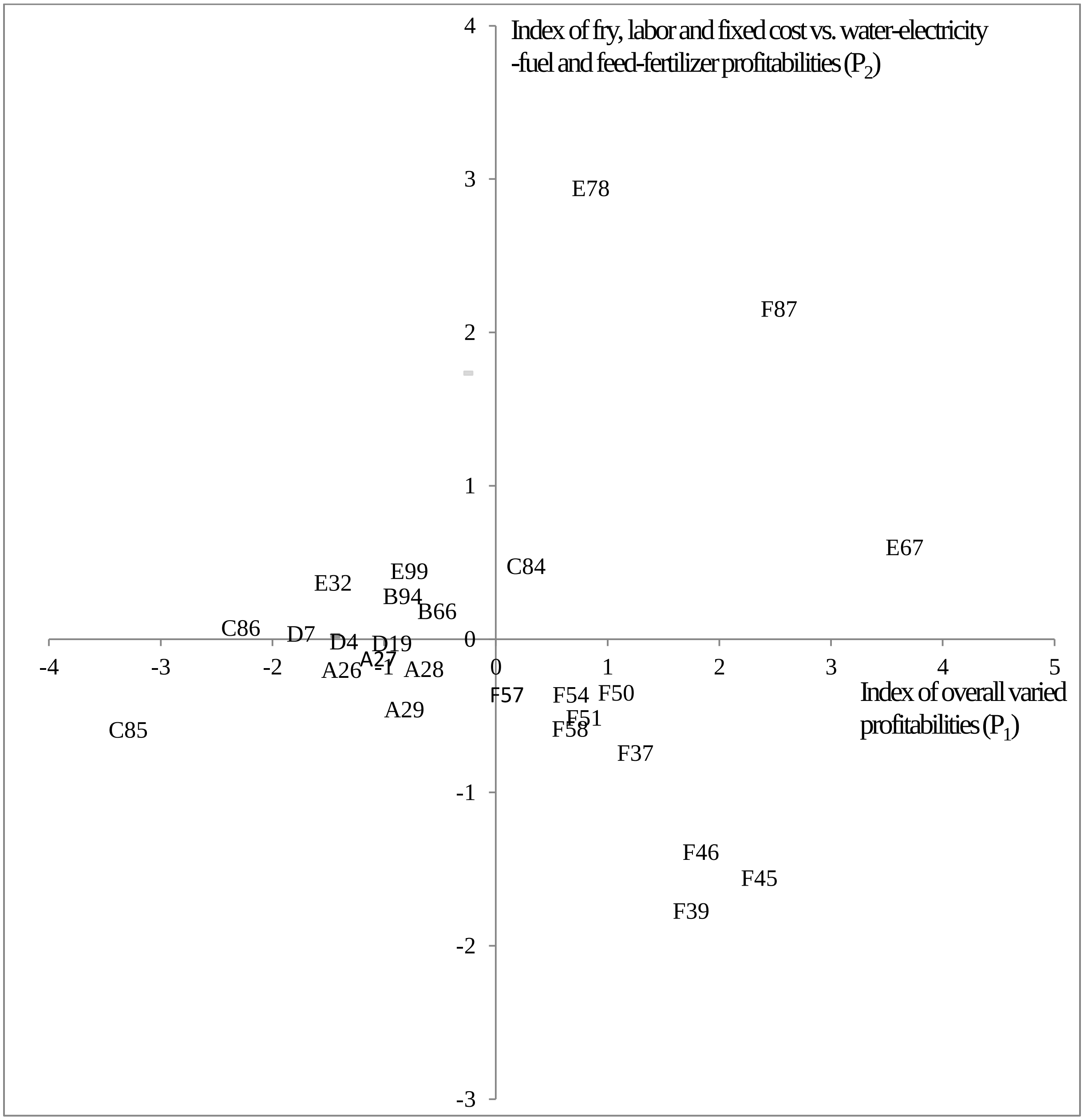
Fig.10 Input intensity's Comparison between Two Production Scales: Less than 1 Hectare (Small Scale) and between 1 and 6.5 Hectares (Large Scale)

Fig.11 Distribution of 28 Tilapia Grow-out Farms based on Two Principal Components (I_1 and I_2) Computed by Input Intensity Variables



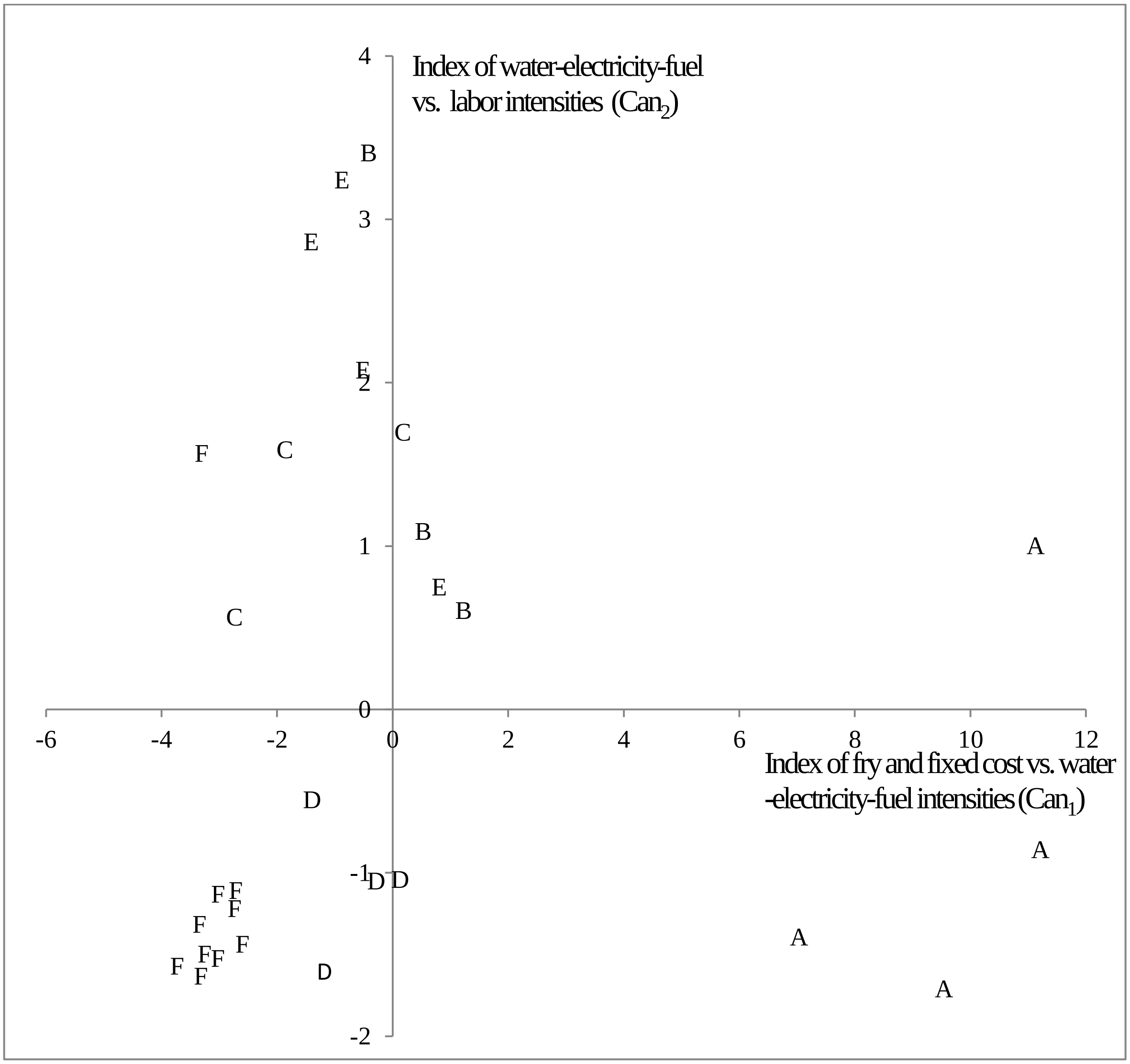
A: small scale-north	D: large scale-north
B: small scale-middle	E: large scale-middle
C: small scale-south	F: large scale-south

Fig.12 Distribution of 28 Tilapia Grow-out Farms based on Two Principal Components (P_1 and P_2) Computed by Varied Profitability Variables



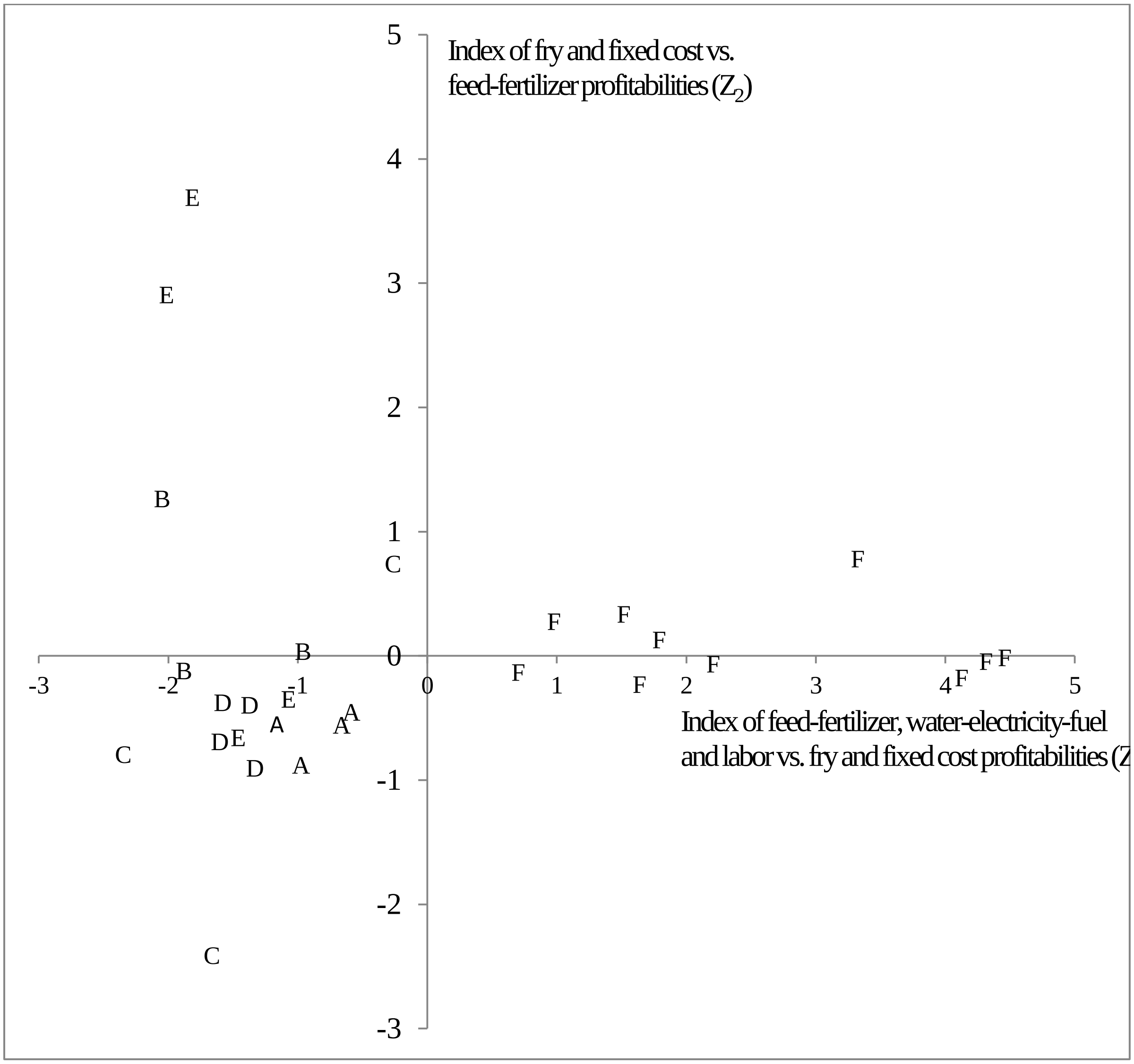
A: small scale-north	D: large scale-north
B: small scale-middle	E: large scale-middle
C: small scale-south	F: large scale-south

Fig 13 Distribution of 6 Group of Tilapia Grow-out Farms based on Two Canonical Variables (Can_1 and Can_2) Computed by the Input Intensity Variables



A: small scale-north	D: large scale-north
B: small scale-middle	E: large scale-middle
C: small scale-south	F: large scale-south

Fig. 14 Distribution of 6 Groups of Tilapia Grow-out Farms based on Two Canonical Variables (Can_1 and Can_2) Computed by the Varied Profitability Variables



A: small scale-north	D: large scale-north
B: small scale-middle	E: large scale-middle
C: small scale-south	F: large scale-south