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The impacts of integrated homestead pond-dike systems in relation to production, consumption and seasonality in central north Bangladesh

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Keywords: Integrated Agriculture Aquaculture, Pond-dike, productivity, wellbeing, location, consumption, seasonality.

Abstract

The roles of homestead ponds and surrounding dike production of vegetables on farms in peri-urban and rural communities in Central North Bangladesh were assessed. A baseline survey sought to characterize actively managed ('active') pond-dike systems, producing fish and vegetables, in terms of productivity and impact compared to less intensively integrated (passive') and control, no-pond households. A longitudinal survey was carried out over 12 months to explore the relationship between seasonality and livelihood outcomes in relation to location and well-being status.

Active homestead pond operators tended to have greater access to information and credit compared to passive and non-pond households; this was likely linked to their greater literacy and greater social connectedness. They enjoyed higher incomes through fish sales and consumed more fish than passive households, which was related to their higher production, in turn explained mainly by the use of more inputs. All active, 50% passive and 38% non-pond households were involved in vegetable cultivation; however, significantly more vegetables were produced by active than others. The impacts of pond-dike production were more critical for food vulnerable, rural households than peri-urban households prior to monsoon rice harvest; worse off households suffered more prior to the 'irrigated rice' harvest. Fish and vegetables raised on farm were most important during lower income months. The study supports the view that small homestead ponds can contribute to the wider food supply, and that such 'quasi peasant' forms of aquaculture contribute to reduced poverty and enhanced dietary diversity and food security in the broader population.

Introduction

Integrated farming involving aquaculture defined broadly is the concurrent or sequential linkage between two or more activities, of which at least one is aquaculture (Little and Edwards, 2003). The key characteristic of integrated agriculture-aquaculture systems (IAA) is the flow of resource or synergisms among subsystems (Little and Muir, 1987; Ruddle and Zhong, 1988; Edwards, 1993; Lightfoot et al. 1994; Dalsgaard and Prein, 1999; Prein, 2002). IAA systems occur when an output from one subsystem which otherwise might have been wasted, becomes an input into another subsystem. (Little and Muir, 1987; Edwards et al. 1988). The advantages and purposes of the integration are increased diversification, intensification, improved natural resource efficiency, increased productivity and increased sustainability (Dalsgaard and Prein, 1999; Prein, 2002). Excavation of ponds occurs for a variety of reasons (Little et al. 2007) and results in raised dikes suitable for the production of vegetables and fruit, i.e. flood-free but with immediate access to irrigation water. Such 'integrated pond-dikes' on smallholder farms therefore have potential to support self-sufficiency in a diverse range of food items (Nhan et al. 2007; Nhan et al. 2008). The traditional roots of IAA based on ponds were in southern China (Ruddle and Zhong, 1988) and strongly linked to land and nutrient-limited food production systems.The sediments of such ponds acted as nutrient sinks and their regular removal and reuse in surrounding agriculture critical to ensuring food security. In the modern era of relatively cheap and available nutrients, on-farm water storage and reuse as become a more important motivation for IAA (Karim, 2006; Nhan et al. 2007; Nhan et al. 2008).

In general, aquaculture has the potential to reduce poverty directly or indirectly (Edwards, 1999; de Janvry and Sadoulet 2002; Kassam 2013) through establishing and strengthening food consumption linkages but also through “income linkages,” and “employment linkages” (Ahmed and Lorica 2002; Belton et al. 2011; Belton et al. 2014). Reducing poverty in low-income countries through smallholder development remains compelling where the majority of people live in rural areas, and agriculture remains the largest single source of employment (Hazell et al., 2010; Wiggins et. al. 2010; Otsuka et. al. 2016). In Bangladesh, direct benefits from aquaculture are largly determined by the availability and access to assets and thus, the capacity of poor people to benefit from aquaculture occurs mostly through indirect food consumption linkages (Roos, Wahab, Chamnan, & Thilsted, 2007; Belton & Little, 2011; Toufique and Belton, 2014; Bogard et al. 2017). The reliability and generalizability of research aiming to clarify the outcomes of aquaculture on poverty have often been compromised because they are based on case studies and/or limited in geographical scope, and are designed with variable degrees of methodological rigour (Bene et al. 2016). With limited exceptions (Hallman et al.2003; Irz et al. 2007; Belton and Azad, 2012; Belton et al. 2016), studies that relate aquaculture to poverty alleviation do not explicitly categorize households according to their poverty status, limiting their analytical precision, while the majority of the longitudinal analyses (Hallman et al. 2003; Rand & Tarp, 2010; Thompson et al. 2006) compare data from two time periods only, and thereby fail to capture the nuances of seasonality. A major ommission has been the assumption that ponds are managed to produce only fish, rather than having become crucial to on-farm irrigation of vegetables and fruit in Bangladesh and much further a field (Pant et. al. 2014).

Attempts have been made in Bangladesh to promote vegetable cultivation alone and integrated with other farming components (such as pond and livestock) to meet the gap between supply and demand, and improve households food and nutrition security as well as increase income (Weinberger and Genova, 2005). In Bangladesh, the improved returns from vegetables produced on pond-dikes compared to fish culture alone have been identified (Shamsuddoha and Janssen, 2003). However, a comprehensive understanding of the linkages between the systems with respect to nutritional and income benefits, or impacts of seasonality are unavailable. Bangladesh has placed emphasis on diversified food production, employment and income generation activities at the farm level similar to many other countries in order to achieve food security in its Poverty Reduction Strategy (Bangladesh Planning Commission, 2005; Murshed-E-Jahan et al. 2010).

Undertanding the potential mechanisms through which aquaculture and IAA might contribute to poverty reduction needs to be framed in the known factors characteristic of poor people in the country, i.e. a lack of assets, particularly land, and high levels of vulnerability (Paul and Routray, 2011; Vadacchino et al. 2011). Aquaculture is undoubtedly more common among better-off households in rural Bangladesh (Belton and Azad, 2012) but a major issue is if poorer farming households can benefit and if so, in what ways. Functional landlessness affects almost half the rural population limiting such people to produce enough food for themselves. Thus, 'homestead' vegetable gardening, possible even on the small areas of land, has emerged as a potential strategy in recent studies (Bouis, 2000; Davidsson and Honig, 2003; KHI, 2003) as a food security (Belton et al. 2012) and poverty focused intervention. The shortage of agricultural land suggests that intensification and diversification through IAA, such as pond-dikes, may be a good strategy for improving the life quality of the poor (Murshed-E-Jahan et al. 2010; Murshed-E-Jahan and Pemsl, 2011). An important role may well be improved access to nutritionally limiting food through the seasons since lower levels of consumption of key foods occur during 'hungry gaps' (Abdullah and Wheeler, 1985; Ahmed et al. 2005). A key benefit of integrated farming may therefore be their role in providing a buffer in the "hungry gap" of poorer households meeting not only their immediate food (eg. fish) needs but also to smooth seasonal cash shortages (Belton et al. 2012), the pond serving as 'bank in the water' (Béné, 2009). Moroever, pond-raised fish may act as more easily liquefiable assets that can be sold to acquire income, similar to the demonstrated role of livestock within smallholder systems (Little and Edwards, 2003; Helgeson et al. 2013). Productive ponds can result in fish surplus to subsistence requirements entering markets and benefiting the broader community (Edwards and Demaine, 1997; Islam et al. 2004; Little and Bunting, 2005). Smoothing consumption of fish can, in principle, relieve hungry periods common in post-disaster situations and positive impact on expenditure and income (Little et al. 2007). The importance of homestead ponds supporting livelihoods directly though food consumed by the producer household compared to indirectly through generating cash through the seasons has remained largely unexplored.

Aquaculture in Asia has has often developed fastest around urban centres but the impacts of location are often ignored in interpretations of status and trends in the sector (Little and Bunting, 2005). Urban, peri-urban and rural areas are interlinked in terms of resource flows and can enjoy mutual benefits (Karim et al. 2011). Dwellers of urban cities such as in Dhaka absorb huge amounts of food and depend largely on surrounding peri-urban areas for food supplies though the variation in infrastructure affects travel time can greatly affect the strength of linkages to markets. Thus, peri-urban IAA can provide good access to food; a source of income, employment and good quality food for the poor; and offer the possibility of savings and returns on investment for middle income families (UNDP, 1996). The level of farmed fish consumption in urban areas has increased consistantly over decades in Asia, which is particularly significant in Bangladesh, as fish is the most important food after rice in terms of share of the food budget and real incomes have improved (Reardon et al. 2014).

Promotion of homestead pond-dike systems holds potential for improving nutritional security through increasing the availability of micro-nutrient-rich fish and vegetables for both farming households and non-farming consumers (Roger and Bhuiyan, 1995). Considerable nutritional benefits are reported to result through pond-dike systems either from direct consumption or from expanded income that supports purchase of other cheaper foods, which benefit household food consumption (Ruddle and Prein, 1998; Ahmed and Lorica, 1999; Thilsted and Ross, 1999; Prein and Ahmed, 2000; Sultana, 2000).

In Bangladesh there has been a major shift away from diverse capture species towards consumption of a limited number of farmed fish species, whilst at the same time the level of fish consumption has increased by 30% between 1991 and 2010 (Bogard et al. 2017). The per capita fish supply increased from 7.6 kg/capita/year in 1990 to 19.2 kg/capita/year in 2013 (Food Balance sheets, 2016). The share of aquaculture in overall fish supply has increased from 16% to 55% over three decades (DoF, 1994; 2006; 2015). This growth has taken place as a result of astonishing development around 'upstream' (farm, seed and feed supply networks etc.), 'mid stream' and 'downstream' (transportation, wholesale and retail markets etc.)' segments of the value chain.

However, limited information is available yet about the dynamics of food consumption and their links with seasonal changes, income and expenditure in Bangladesh, though these are often associated. Comparative analysis with respect to location (rural and peri-urban), wellbeing and farming system is important because it was anticipated that the level of wellbeing and location are likely to affect households' level of adoption and adaptation of pond-dike systems. Further, the contribution of fish to household food and nutrition security primarily depends on availability and access on the one hand and cultural and personal preferences on the other. These factors are largely determined by location, seasonality and price (Chastre et al. 2007; Beveridge et al. 2013).

Considering the above context it was hypothesized that households' adopting homestead pond-dike systems have a different livelihood status compared to non-adopting households. The level of well-being, education, age, access to finance and information and location might be expected to impact on adoption, adaptation and rejection of pond-dike systems. This study aimed to clarify the potential role of aquaculture and associated horticulture in smoothing consumption and enhancing income of adopting households. However, the key objectives of the present study are to 1) analyze the livelihood impacts of fishponds integrated within farming system through a baseline survey and 2) exploring the relationship between seasonality and livelihood outcomes (principally-income and consumption) in relation to location and well-being, for households actively managing their pond-dike systems.

2. Materials and methods

2.1. Farmer selection process

A total of six villages were selected from six sub-districts identified as being rural or peri-urban locations in Mymensingh district where Participatory Community Appraisals (PCAs) (Karim, 2006) had previously been carried out. Villages were identified as rural and periurban on the basis of access to markets as indicated by distance to the nearest district centre. Well-being ranking exercises were conducted to categorise participating households broadly into two socio-economic levels viz. better-off and worse-off (Mukherjee, 1993; Adams et al. 1997).

A baseline survey was carried out from December 2002 to January 2003 with a total of 205 farming households categorized into three groups based on the PCAS i. 'active' (pond water used to irrigate vegetable crops), ii. 'passive' (dike space used for crops, typically perennials, without irrigation) and iii. 'non-pond' (households with no access to a pond but producing vegetables; Karim et. al. 2011). The households were selected randomly from a village registration list. The sample size was 30 (2 wellbeing X 3 farming systems X 5 representatives) from each village totaling a minimum of 180 households from 6 villages; additional households were sampled and a total of 205 were interviewed. A total of 72 active integrated households were subsequently monitored over a twelve months period from April 2003 to March 2004 through a total of 864 separate interviews to determine seasonality issues. Links between seasonality (especially critical rice pre-harvesting periods) and vulnerability were observed during the seasonal calendar exercises of the community appraisals and then in more detail through the households' longitudinal monitoring study.

2.2. Questionnaire design and interview process

The questionnaire covered household level information to assess the nature and level of different assets (natural, social, financial, human and physical) implicit with the livelihood framework. It also included questions related to the vulnerability, coping strategies, and transforming structures and processes. In general, the head of the household was interviewed; however, his/her spouse and other family members were also commonly present and participated. Participants were asked about the types of food they consumed along with frequency (meals/week) and source in the last seven days prior to the survey day. The active integrated farmers were monitored through repeat interviews of the same household head and available family members monthly over the following 12 months resulting in a total of 864 separate interviews. This study used a modified “dietary history recall method” in which consumption was assessed on the basis of a 72 hour recall period and crosschecked with availability of food items using a checklist at community level (Klaver et al. 1988).

3.3. Data analysis

Initially data were recorded in Microsoft Access™ database before exporting to Microsoft Excel™ for exploratory numerical analysis (descriptive statistics, graphs, pivot tables, etc). Based on the initial analyses, a General Linear Model (GLM) (Wimmer and Dominick, 1987; Field, 2005) was used to identify relationships among variables (2 locations, 2 well-being groups and 3 treatment groups). Location, well-being group and treatment groups were included as independent fixed variables. Village was considered as a random variable and nested within location and households for all analysis. All main effects as well as two and three factor interactions were evaluated where appropriate. Homogeneity/normality of data was assessed (Roscoe, 1975) prior to analysis and non-normally distributed data were transformed using logn or square root transformations. Inputs and output costs were based on prevailing farm-gate prices and labour inputs assessed through recall. Output was considered as the amount of fish and vegetables sold and consumed. Financial performance was assessed through analysis of gross returns (sale+ consumption value), gross margins and returns to labour and investment. Gross margin refers to value (gross return) of fish or vegetable (both sale and consumption) minus total variable cost (all inputs). All statistical differences were considered significant at the 5% level.

3. Results

a. Baseline survey

3.1. Livelihood assets portfolios:

3.1.1 Human capital

The mean household size of the survey population was 6 (±2) while the mean age of the respondents was 47.41 (±14.3) years. The literacy level was significantly higher among the household heads of active (76%) , than passive (58%) or non-pond (44%) households (Table 2). The mean illiteracy rate of the worse off household heads was more [$\chi 2(1)=25.68$, $P=0.001$] than double (55%) that of better off (20%) households. The literacy rates in the rural and peri-urban areas were 57 % and 68%, respectively, although the difference was not significant. Active households' literacy levels were higher ($P<0.05$) than passive and non-pond households; conversely, illiteracy rates of non-pond and worse off farming household were higher than any other groups.

3.1.2 Natural capital

The overall average land holding of all households was 0.9 (±0.9) ha but varied from 0.02 to 5.51 ha (Table 2) which is within the range considered as small or marginal land holders (Belton and Azad, 2012). The average land holdings did not vary significantly ($P>0.05$) between active (0.967±0.84) and passive groups (0.997±1.04 ha) while non-pond households (0.636±0.604) had significantly less ($P<0.05$) land than both groups of pond owners. Land holdings also varied significantly ($P<0.05$) between better off (1.31±1.06) and worse off (0.5±0.36) households. Pond operating households, both active and passive, had larger land holdings ($P<0.05$) than non-pond households (Figure 1). Better off households' owned significantly ($P<0.05$) more land compared to worse off households but active (worse off) had less land than passive (better off) households. Poorer households leased in more land than richer both in rural and peri-urban areas.

3.1.3 Social capital

A total of 30% of farming households had an affiliation with an organization (local, international, autonomous) as a participant and/or employee. Irrespective of category, the household head in most (88%) families, in almost all cases a man, was the key person who had access to information, followed (in 10% of households) by a son. In a very small number of families (5% and 2%), wives and fathers of the respondents respectively played such a role of main information conduit.

3.1.4 Physical capital

The physical capital owned by households included houses constructed of various qualities of materials (tin, wood, brick, soil and tin), means of transportation (bi-cycle and motor-bike) and other property (radio, tape recorder, television, water pump and agricultural machinery). Only a few households owned a non-motorized pulling van (4%), rickshaw (5%) or motorbike (1%). The largest (35%) percentage of households with a bicycle were in the pond-dike active group. Livestock were important assets with chickens being reared by almost all (92%) households followed by cattle and ducks. Integrated (active and passive) farming system households had more ($P<0.05$) chickens and ducks compared to non-pond households, while better off households had more ($P<0.05$) chickens than worse off.

4.1.5 Financial capital

Around 39% households took credit from different formal and non-formal institutions The highest proportion of indebted households accessed credit from their neighbours (53%) followed by national NGOs, banks, village cooperatives and local NGOs respectively (Table 2). Active and passive households borrowed more money than non-pond groups. A higher percentage of worse off households' accessed credit though the amount was lower than better off households. About one third of the households surveyed could borrow money from their neighbours and relatives without incurring interest. Nearly the same number of households of the two different well-being categories had access to credit although better off households tended to take on more debt ($P<0.05$) than worse off households.

4.2 Transforming processes and structures

4.2.1 Access to information and market

A significantly higher percentage (32%) of active households had access to multiple sources of information, mainly from the Department of Fisheries (DoF) and relatives, compared to passive (16%) and non-pond (5%) households. A higher percentage of better off households had access to services from the Department of Agricultural Extension (DAE) than worse off, while more worse off households had greater access to NGOs than better off households. A higher percentage of rural households had access to both DAE and DoF than peri-urban households. On the other hand, NGOs were more important as a source of information to peri-urban than rural households. Farmers received different types of information which also varied from one farmer to another, however, when disaggregated by type into three major categories, viz. agricultural technology, fish culture and crop and fish disease, it was found that significantly more active households received information on "fish culture" (26%) than passive groups (10%) (Figure 2).

A higher percentage of active (69%) households sold fish than passive (52%) and more peri-urban households (70%) sold fish than rural households (54%) regardless of group.The other households retained all their fish for family consumption and local gifting. Most sales of fish were dependent on middleman but the proportion was higher among rural households than for peri-urban (82%).The remaining households sold fish directly. The majority of households sold fish to intermediaries at the local market (54%), followed by the farm gate (29%) and auction market (22%) (located at the sub-district, district or in the city). An average of nearly half (47%) of sampled households sold vegetables through intermediaries (83%) and directly (20%) to the consumers.

4.3 Livelihood strategies

4.3.1 Occupation

Among farming groups, agriculture was the primary occupation of 70% of active integrated households, 76% of passive integrated households and 56% non-pond households (Table 1). Rural people were found to be more dependent on agriculture (74%) and less on service, whilst peri-urban households were relatively more likely to be employed in Government or Non-government organisations. In this study around half (48%) of the sampled household heads' had a secondary occupation in addition to primary occupation. Fish farming was a significant secondary occupation of active group household heads (18%) after rice (41%) and relatively more important among this group in rural (24%) than peri-urban (11%) locations but envisaged as a similar priority secondary occupation to both better-off (11%) and worse off households (10%).Poorer, non-pond households had ex-farm orientated livelihoods.

4.3.2 Farming systems

Fish culture and vegetable cultivation

A higher percentage of active households used organic and inorganic fertilizers, rice bran, wheat bran, oil cake and insecticide as pond inputs compared to passive households . Most (86%) of the farming households had access to organic fertilizers from their own farm, but some purchased from the market (14%) or obtained from neighbours (11%). There was no significant association ($p<0.05$) between organic fertilizer source, group and well-being level. Rural households were more likely to use organic fertilizers produced on-farm than peri-urban who were more likely to purchase it. Active households also stocked fish seed more frequently ($P<0.05$) (2.6±2.3 times/year) compared to passive groups (1.5 ± 0.7 times/year). Fish seed stocking frequency was also affected ($P<0.05$) by location and well-being (Table 3). Only 7% households pumped water to their ponds from a deep (DTW) or shallow (STW) tube well, the majority being recharged by rainwater and/or seepage from a high water table.

Harvested fish yields were 164.4±195.6 kg hh^{-1} $year^{-1}$ irrespective of location, well-being and groups (Table 4). Fish production (kg hh^{-1}) varied between wellbeing ($P<0.05$) categories, location and also between active and passive groups. Vegetable cultivation was practiced by 60% of the households among the overall sample. All active, 50% passive and 38% non-pond households were involved in vegetable cultivation. The mean amount (414.21±724.71 kg hh^{-1}) of vegetable produced by active households was significantly higher ($P<0.05$) than passive groups (345.7±715.1) kg hh^{-1} and non-pond (256.5±243.1kg hh^{-1}) groups (Table 4). Passive and nonpond groups' vegetable production (kg hh^{-1}) were similar (P>0.05). There was no significant difference (p>0.05) in terms of vegetable production (kg hh^{-1}) between locations, while better off households produced significantly (P<0.05) more than worse off households. Ponds were the main water source (87%) used by vegetable growers. All active households used water from their ponds; in addition about (20%) and (3%) households also used water from STW and DTW, respectively (Table 5). Worse off households applied water to their vegetable crops more frequently than better off households. A large percentage (76%) of passive integrated households also depended on pond water and some non-pond households (25%) had access to their neighbour's pond water.

4.4. Livelihood outcomes

4.4.1 Income and expenses

The majority of the households (98%) depended on farm income streams (derived from sales of rice, fish, vegetable, poultry etc) and 59% on non-farm (service, business, labour etc) (Table 8). All active and passive households were dependent on on-farm activity for their livelihood, whereas 87% of non-pond households were engaged with on-farm enterprises. All better off households earned income mainly from on-farm activities, which contributed 77% of their total income, while 95% of worse off households were involved in on-farm activities; it only contributed 67% to their total income (Table 8). Fish and vegetable culture contributed 17% and 8% to overall on-farm income sources, respectively. Total income (US$ hh^{-1} and US$ $capita^{-1}$) varied among groups (P<0.05) and between well-being (P<0.05) categories. The higher non-farm income of non-pond households did not substitute for the much greater farm incomes on farms with ponds; mean household incomes of households without ponds were around one third lower (US$1007 hh^{-1} compared to 1,379 and 1,508 for active and passive pond households respectively). (Table 8). The majority (27%) of the households' monthly expenses ranged between US $ 8.5-17.0. There was no significant association [$\chi2(2)=11.21$, P=0.06] between expenses and group. Peri-urban and better off households' expenses tended to be higher ($P<0.05$) than rural and worse off households respectively.

4.4.2. Fish and vegetable consumption

On average active households consumed fish at least once a day, whereas passive (4.9 times $week^{-1}$) and non-pond (4.05 times $week^{-1}$) households' consumption frequency was significantly ($P<0.05$) lower. Fish consumption frequency also varied significantly ($P<0.05$) between the well-being groups but not between locations. A higher proportion of better off households consumed fish from their ponds than worse off. A higher proportion (37%) of active households tended to consume more wild fish than passive and non-pond groups (Table 6). Better off households also consumed more fish from ponds (culture) than worse off. More peri-urban people (63%) depended on fish purchased at the market compared to rural (42%) (Table 6).

The average consumption frequency of leafy and non-leafy vegetables was 3.6 (±2.1) and 4.2 (±2.4) times weekly respectively. Among the better off, active households consumed leafy vegetables more frequently ($P<0.05$) than passive and non-pond groups, while worse off households consumed at a similar frequency. Among the groups, active groups harvested more leafy (29%) and non-leafy vegetables (43%) from pond dikes than passive groups, while a higher proportion of passive households grew both leafy and non-leafy vegetables onplots adjacent to their house than others.

b. Year round monitoring

4.5. Income:

Weekly average income (US$ capita^{-1} week^{-1} and US$ hh^{-1} week^{-1}) of the better off was significantly ($P<0.05$) higher than worse off households. (Figure 3). Peri-urban households were found to be more dependent on fish sales (27% of total income) than rural households (11% to total income). Peri-urban household income was likely to be higher ($P<0.05$) than rural in most of the months, except February, April, May and be independent of well-being level. The contribution of rice sales to the overall farm income (US$ hh^{-1} week^{-1}) was highest followed by fish, livestock, poultry and vegetable. Fish sales were relatively higher in the months of July, August, October and December irrespective of well-being level, while households sold relatively less vegetables in the months of July, August and October. Winter season (October, November and December) were the peak months for vegetable sales for the better off households in peri-urban locations (Figure 4).

4.6.Household expenses

Among all the expenses it was revealed that food accounted for 20% of total expenses, followed by agricultural labour (19%), rice cultivation cost (13%), house maintenance (9%), pond input (8%), health (5%), education (3%), vegetable input (2%) etc irrespective of location and well-being level. Expenses for purchasing food were similar throughout the year though expenses on food surged in November (Figure 5). Better off households' had higher labour expenses (per households and per capita) than worse off.

Better off households' (per household and per capita) also spent more ($P<0.05$) for pond inputs than worse off. Such costs were highest in the main growing season especially between April to July and lowest during the coldest period (November to January). Expenses (US$/capita/week) for pond input varied by well-being level ($P<0.05$) and month ($P<0.05$). In August and November expenses for vegetable inputs was higher than other months for both better off and worse off households.There was no significant difference for vegetable input cost by location, well-being category or month. There was a positive correlation between overall income and expenditure (r=0.352) on food purchases (r=0.287), agriculture wages (r=0.466) and pond inputs (r=0.264).

4.7. Consumption of fish and vegetables

Rice was the major food item accounting for 48% of the total food consumption followed by non-leafy (23%) and leafy (10%) vegetables and fish (8%) to the total food consumed irrespective of well-being categories across the locations. The average amount of fish consumption (g/capita) tended to peak in the month of April (1,037±1,185 g capita^{-1} week^{-1}, 1,342±1,510 g AE[1] $^{-1}$week^{-1}) at peri-urban locations and then decline over subsequent months. In contrast, consumption was more consistent in rural areas; consumption (g capita^{-1} week^{-1}) was highest in the months of October and November and lowest in the month of April (369±326 g capita^{-1} week^{-1} and g AE^{-1} week^{-1}). The least fish was consumed between November and April. Overall, February, March and April were the months when least fish was consumed irrespective of location and well- being. 62% and 52% of the total fish consumed (g capita^{-1} and g AE^{-1}) was produced on-farm by better off and worse off households respectively. The second important source was markets, followed by wild stocks

[1] The number of adult equivalent (AE) units of a household is determined by assigning different values to the household members (adult male=1). The weights are standard and depend on the age and sex of individuals (Ahmed, 1993)

and gifts received from neighbours and relatives. Worse off households depended more on wild stock (21%) than better off (16%). Better off households tended to consume greater amounts of fish from their own farm in most of the months of the year, except May (Figure 6).

Non-leafy vegetables were least consumed in the months of April, May and June and intake peaked between December to March. Households consumed more non-leafy vegetables produced on-farm in the months of July, August, December to March compared to other months ($P<0.05$). On average, peri-urban households purchased 34% more non-leafy vegetables from the market than rural households. The latter tended to depend more on their own production, especially in the months from May to August. Households depended more on their own production than the market for leafy vegetable consumption, while a higher proportion of non-leafy vegetables were purchased from the market compared to produced on-farm.

4.8. The vulnerability context of active integrated households

Seasonal calendars produced by focus groups during the PCA helped understanding of the household vulnerability context for different well-being groups (Table 7). In addition, seasonal changes in natural conditions included water scarcity during the dry season which has been reported during the PCA. In contrast, an outcome of the Farmer Participatory Research (FPR) monitoring workshops was the impact of flood destruction of some fishponds in the research locations during the trial period (Karim, 2006). Due to the great seasonality in precipitation, agricultural diversification depends heavily on the availability of irrigation water in both rural and peri-urban areas (Table 5). It was noted that, in half of the communities investigated (one rural, two peri-urban) off-farm irrigation was either unavailable or too inconsistent and vulnerability levels were comparatively higher.

Seasonal calendars helped understanding of the complexity of vulnerability of the households in different locations. Food deficit months were perceived differently by households of different well-being levels and also between locations. Better off men and women were found to suffer less from food shortages than worse off households. Rural households were more vulnerable to food shortages than peri-urban households prior to harvesting the ‘monsoon rice’ crop, while worse off households suffered more prior to the ‘irrigated rice’ harvest. There was no major difference between locations (peri-urban/rural) for food shortage related vulnerability during this period.

Households irrespective of location and well-being level suffered from different health problems mainly from mid October to mid March and also during the period from April to June. There were no important differences between location and gender, while worse off households irrespective of gender and location appeared to be affected more by health problems in terms of duration and types of diseases than better off households.

5. Discussion

The capacity of stand-alone aquaculture to provide direct benefits to the poor in terms of income or consumption has long been questioned, at least in Bangladesh (Lewis, 1997; Toufique and Gregory 2008; Toufique and Belton 2014). But the concept of aquaculture only occurring on mono-commodity ‘fish farms’ misinterprets their role in many low income, food deficit countries (LIFDC) where the practice has become widely established within farming communities. Prior to the recent take off of entrepreneurial, commercially-orientated pond aquaculture (Belton et.al., 2016), there had been a long period of organic spread of low intensity carp farming linked to the increasingly ready availability of hatchery-produced juveniles in Bangladesh. Using the raised, flood-protected pond dikes to produce vegetables has become a *de facto* opportunity and the relationship between the two activities has long deserved greater scrutiny. This widely practiced, but little researched use of pond dikes to produce vegetables was hypothesised as being a key incentive for sustained adoption of the overall system. The documented rapid expansion of the commercial aquaculture sector in recent years (Belton and Azad, 2012) but the share of production from larger farmers (0.4 ha or more of ponds) stood at 53% of the total volume of fish in 2014 which was similar to 2004, while the share from other categories (35% and 11% for medium and small respectively) of farmers (<0.2 ha) who were the focus of this study remained stable (Hernandez et al. 2017). The current study, although undertaken more than decade ago, remains relevant in the current supply context although aspects of demand may have changed; Bogard et al (2017) found that more than nationally 70% of fish were now purchased in rural areas. The study used a livelihood framework to assess relationships to production to which we first turn before considering the characteristics of adoption. We assess the importance of location and household socio-economic status on the level to which integration occurred and the benefits thus derived. The interrelationship of seasonality and vulnerability is then dissected before attention is drawn to discussion of the impacts of pond dikes on income and consumption smoothing.

5.1 Livelihoods of adopting households

A lack of assets among poorer households, in particular land and a pond, has been identified as a key constraint to them gaining direct benefits from aquaculture (Belton, Haque, and Little, 2012; Toufique and Belton, 2014). Ownership of, or access to, resources is a critical factor determining the adoption of a technology (Savadogo et al. 1998). This study showed that active and better-off households were more likely to own their own ponds, and indeed other tangible assets such as livestock, than the passive and/or worse-off. However it was clear that the opportunity to lease ponds was widening access to poorer people. Worse-off households leased in relatively more land compared to better off which perhaps suggests that encouraging a land rental markets would be a pro-poor policy. An analysis of an aquaculture nursery cluster area in West Bengal found a dynamic market in pond leasing had both opened up opportunities for poorer households and stimulated intensification and productivity gains (Barman et. al., 2006). It is likely that the sample failed to capture the 'extreme poor' (BBS, 2011;Toufique and Belton, 2014) within the non-pond group that were more likely to be landless and absent from their home communities seeking wage labour (Zug, Sebastian. 2006; Shonchoya, Abu S. 2011). In the current study 72% of the 'worse-off 'households actively or passively used their own pond water, indicating a comparatively higher resource status. However, around 25% of the non-pond households growing vegetables used water from their neighbours' pond which reflected the the role of ponds in social capital and how such integrated systems can directly, though partially, benefit the broader community.

Fish culture was clearly a secondary activity for both better and worse off active households, reflecting a similar level of importance of aquaculture to these groups (Bestari et al. 2005). Similar scenarios still prevail in the villages close to the study area where aquaculture was perceived as the secondary occupation (Belton at al., 2014).

Although in general ownership of a pond and active management correlated with a higher level of wealth, active management of ponds occurred across the socioeconomic spectrum suggesting that size of land holding or level of poverty was not a major constraint. A recent study of marginalized *adivashi* farming communtiies in Bangladesh found even ditches and extremely small ponds were managed successfully following appropriate interventions (Pant et al, 2014).

Active, and rural households' had greater access to 'credit' and 'interest free credit' than other groups reflecting their interest and capacity to pay back, while the indebtedness of a relatively larger proportion of poorer households' probably indicated the greater need than better off households. Although relatively few producers relied on credit to finance their pond-dike system this might reflect their relatively low productivity and a reluctance to risk more resources (Karim et al. 2011). Active pond operators tended to have greater access to information and access more credit; likely linked to their greater literacy and greater social connectedness. The poor in Bangladesh, irrespective of gender and education, depend on rural money lenders who charge high interest rates on unfavorable terms and conditions (Mahmud, 2010; Hossain, 2013). Households showed higher dependency on 'credit' and 'interest free credit' for carrying out agricultural activities. However we speculate that financial support is crucial for poorer households to adopt improved management practices. Although 'money cannot solve all problems, it can solve many of them'; credit is therefore very useful (Hallman et al. 2003).

In previous studies in Khulna, Southwest Bangladesh where production is orientated around freshwater prawn production, it has been suggested that farmers underutilized the potential for dike cropping around the *ghers*, partly because they lacked knowhow, especially how to innovate and continually adapt systems and transfer knowledge among one another (Chapman, 1997; Smit and Wandel, 2006; Anik and Khan, 2011). Recent studies (e.g. Howson, 2014, Taskov, 2014) in the same area however point to more dynamic and adaptable farming communities in which increased dike cropping is related to changes in salinization and market opportunities, reflecting a growing shared capacity for innovation. The importance of relatives and neighbours in information transformation, rather than formal institutions, was shown in the current study and how location impacted on it. Overall, more rural households accessed information than peri-urban while periurban households had more affiliations (as participants) with formal institutions than rural. Sources of information might be expected to influence farmers' decision-making ability in relation to farming practices, resource management and development (Vadacchino et al. 2011). However, it is evident from this study that knowledge is available but not equally accessible and distributed across study locations.

5.2. Differentiated farming systems

The higher fish production achieved by active, better-off and peri-urban households than by passive, poorer and rural households reflected the greater level of nutrients used. In turn, this reflected better integration into markets and greater investment. Better-off households produced around double the amount of fish than poorer households, reflecting larger pond size as well as higher yields. Overall yields were comparable to control farms in an on-farm trial in the same area but were a fraction of the yields achieved by households (+200% to >5MT ha^{-1}) that increased their levels of nutrient inputs (Karim et al, 2014).This reflects the underperformance of most farms compared to their potential, although large variation between farms was clearly evident. The influx of many new producers to the sector over the last decade following relatively intensive practices contributed significantly, while the smaller homestead pond farmers hgenrelaly continued to follow less intensive practices and contribute a smaller share of overall national production

Homestead ponds which is often refered to as a ‘low input activity for household consumption’ in Bangladesh (Dey et al. 2008), have relatively less impact on consumption outside of the producer household, given that they now make up an estimated 11% of supply farmers (Hernandez et al. 2017). A recent analysis based on a BHIS dataset shows that the top 2.4% of the fish farming households accounted for 50% of the total production, and farms larger than the homestead ponds in the current study are now by far the main source of pond-fish outputs in Bangladesh (Hernandez et al. 2017).

Training in IAA techniques focused on homestead fish production has been demonstrated to be effective at enhancing productivity, encouraging greater use of recycling on-farm and reduced levels of inorganic fertiliser use in favour of organic (Murshed-E-Jahan and Pemsl, 2014; Karim et al. 2016). The more frequent stocking of seed by rural households, reflects both their higher consumption frequency and dependency on fish from their own ponds than peri-urban households. Poorer households, mostly in rural areas, probably limited purchased inputs because of their actual or opportunity cost. In contrast to fish, vegetable productivity was more similar between better off and poorer, and periurban and rural groups, indicating lower investment costs. Tascov (2014) found that there had been a move towards greater emphasis on dike-based vegetable production by poorer prawn farmers in greater Khulna for this reason.

Access to urban markets appears to have impacts on the utilisation of on-farm inputs. In spite of rural and peri-urban households' having similar numbers of chicken and cattle, the frequencies of organic fertilizer application in ponds was higher in rural communities, whereas households in peri-urban areas relied more heavily on the use of other purchased inputs. Seed is another critical input of both fish and vegetable cultivation, but this input is used by people irrespective of location probably without understanding the quality.

Fish culture in Bangladesh in early 2000 i.e. during the study period was dominated by small-scale low-intensity carp production, which has recetntly been expanded to entrepreneurial pellet-fed culture of Pangasius catfish also known as pangas (*Pangasianodon hypophthalmus*) and tilapia (Ali et al. 2013), and pangas is now by far the most important intensively cultured species in Bangladesh in volume terms (Belton et al. 2011). Pangas was introduced in the early 1990s in Mymensingh district, north of the capital city Dhaka, which spreaded to other districts of the country and rapidly evolved as one of the economically important activity with long backward and forward linkages providing diverse livelihood opportunities for a wide range of value chain actors (Haque, 2009). However, the emergence such commercial fish farms has occurred especially in the main fish farming area of Bangladesh and elsewhere in Asia where there are abundant water resources, communicated well to market, better access to inputs existed (Karim, 2006; Karim et al. 2016, Belton et al. 2016).

Mean fish production (2.06 t ha^{-1}) of the homestead ponds studied was similar to a nationwide estimate (2.4 t ha^{-1}; Bestari et al. 2005), but lower than that observed in Greater Mymensingh district (3.3.t ha^{-1}; DANIDA, 2004). Fish contributed substantially (17%) to the mean on-farm income of households compared to 10% of total income in the DANIDA study. Murshed-E-Jahan and Pemsl, (2014) found that the contribution to farm and total household incomes ranged from 16.8% and 11.2%, respectively for households receiving training and 12.6% and 7.8%, for control households. The variation between studies could be related to differences in sample size (HH) and methodologies used in selecting target groups (Belton and Azad, 2012). On the other hand, the average production (kg ha^{-1}) of vegetables of all households was slightly lower compared than that measured/estimated by another study carried out in Bangladesh by AVRDC (Weinberger and Genova, 2005).

The key role of on-farm ponds for securing nutitional security under rain–fed conditions is suggested by these results. In most cases pond water was by far the most important source for irrigation of vegetables. Households without ponds were not only unable produce fish but were much less likely to produce nutritious vegetables. The smaller areas of ponds of worse-off households' suggests their increased vulnerability and dependence on pond water compared to better off households with larger ponds. In other contexts, ponds managed by poorer households tend to be more seasonal, multi-purpose and to have lower water holding capacity (Pant et al. 2005; Little et al. 2007). The multiple use of pond water may explain famers'reluctance to intensify production through use of more fertilisers and feeds, especially during periods of greatest water scarcity.

5.3 Differential impacts among active, passive and non-pond households

In rural Bangladesh, households mainly depend on on-farm income sources (DANIDA, 2004; Thompson et al. 2005; BBS, 2013). In the present study, dependency on rice was similar between active and passive, while fish (>2.23%) and vegetable (>5.53%) contributed more to the total farm income (US$/hh) of active households than passive. Worse off households benefited relatively more than better off from selling fish. Active and passive households were more dependant on on-farm income than non-pond households. However, the differences in income observed for active, passive and non-pond households was not matched by any differences in household expenditure, which were comparable. A similar finding was observed where expenditures did not differ significantly between adopter and likely-adopter of agriculture technology households inspite of different income levels (Hallman et al. 2003). This could be because expenditure of households tends to relate to their specific demands and preferences.

The study presents evidence for ponds being a key component of sustainable intensification (SI) of smallholder farms in Bangladesh, allowing them to remain the core of liveihoods that enjoy enhanced incomes and improved nutrition. Garnett et al. (2013) identify several key tenets of SI that are characterized by small integrated ponds; productivity is enhanced without expansion in land area used or being dependent on high levels of external resources (water, nutrients); animal welfare remains high since fish densities and mortalities are relativeley low, and enhanced food security is enhanced through production of a range of nutrient-dense foods for consumption and sale. The role of ponds in supporting the rural economy and broader sustainable development is suggested by several key findings of the current study. Moroever, the scope for further intensification through more or less active management of the pond to produce both fish and vegetable suggests how pond construction, through the elevation of earthen dikes, creates additional functional biodiversity –farms with no pond may lack such flood–free areas to produce vegtables (Karim et al. 2014). Households with ponds were less dependent on non-farm income and enjoyed higher overall incomes than households without ponds. Actively managed ponds tended to acheive higher income through fish sales than passive, which related to their higher production, in turn was related to higher inputs. Active households were supported by better access to credit and technical support.

Belton et al. (2012) found that smallholder ponds both supported producer household food security and income and produced marketable excess that befitted non-producing consumers. Per capita fish consumption observed in his study (11.99 kg $capita^{-1}$ $year^{-1}$) was lower than that found in other studies, both in the same area (MAEP;14.03 kg $capita^{-1}$ $year^{-1}$; DANIDA, 2004) and nationally (13.86 kg $capita^{-1}$ $year^{-1}$; BBS, 2000).

Active households benefited more in the peri-urban area from selling more fish than passive and, despite the dissimilarity in production (kg ha^{-1} and kg hh^{-1}), active households consumed fish from their own ponds at a similar level to passive. This supports the findings of previous studies, suggesting that increased production does not necessarily tend to increase consumption in the producer household (Torlesse et al. 2004; Karim et al. 2011). However, an increased supply of fish to the local market, produced by the active households, contributes to overall food security of the population as a whole; rapid expansion of aquaculture increases the fish consumption by the extreme poor and moderately poor consumers and those in rural areas by pegging down fish prices (Dey et al. 2010.,Toufique and Belton, 2014). It also demonstrates how SI of pond-dike systems supports broader susainable development (Garnett, 2013) and how even modest further intensification as demonstrated by Karim et al. (2011) could have major impacts at the population level without any drastic increase in reliance on external resources.

Although subsistence fish consumption in terms of quantity and frequency was similar between active and passive households, active households also consumed more wild fish and fish purchased from the market than passive households. Thompson et al. (2005) observed higher dependence of fish pond owners on capture fisheries than aquaculture for meeting subsistence requirements. However, overall better off households' consumption (amount and frequency) was found to be higher than worse off in this study. Fish were more likely to be purchased by peri-urban households than rural, probably because access to markets was easier. However in general, households with ponds were less dependent on the market for fish supplies than households without ponds. A recent nationwide study by Bogard et al. (2015) found most households sourced fish almost entirely by purchasing from markets.

The per capita vegetable consumption across all HHs was 16.6 kg capita^{-1} year^{-1}, which was much higher than the amount reported in another study in two other Districts (around 12 kg capita^{-1} year^{-1}) (Weinberger and Genova, 2005). Consumption of farm vegetables in terms of frequency (times/week) was different only between well-being categories. Vegetable production (kg ha^{-1}) was higher in active households than passive and non-pond, but production (kg hh^{-1}) was similar, even though the cultivated area was less than in passive and non-pond households, reflecting the greater productivity (kg ha^{-1}) of active vegetable growers.The role of ponds in terms of how their integrated management might have an important seasonal attibutes is now considered.

5.4 Relationship between seasonality and vulnerability

Bangladesh has a wet:dry climate characterised by several months of limited or no precipitation (Shamsuddin, 2010; David et al. 2012).This seasonality greatly affects the availability of surface water and although the country as a whole has witnessed a groundwater revolution in the last three decades based on exploiting both deep and shallow ground water, availability of water during the driest months remains uneven (Shahid, 2010). It was noted that, in three of the communities studied (one rural, two peri-urban) off-farm irrigation was not available consistently.

Traditionally Bangaldesh has suffered periods of vulnerability related to water scarcity, especially regarding availability of food. The best understood periods are the ‘hungry gaps’ that occur prior to rice harvests both the traditional *amon* wet season rice crop and, with the emergence of groundwater irrigation water, the irrigated *boro* crop (Hossain et al. 2006). Households, irrespective of location and well-being level, suffered from different health problems mainly during periods of seasonal change (onset of rains, summer and winter) (cf. Lindenberg, 2002). Financial vulnerability increases when a family member suffer from illnesses, during low income months and during the pre-harvesting period of rice crops. During these periods households sought to *borrow* more money to support consumption expenditure. Households actively managing diversified, pond-based farming systems were able to access credit more easily than non-diversified, non-pond households. Higher numbers of worse off households tended to borrow money than the better off reflecting their greater need and vulnerability than better off households (Little et al. 2003).

Household monitoring results showed that households became most indebted in March (pre-*boro* harvest), and June to September (pre-*amon* harvest) related to relatively low incomes in June and higher expenses (March to June) required for purchasing agricultural inputs. It was clear that the intensity and duration of the food deficit period was higher prior to the *boro* harvest followed by ‘monsoon rice’, which is reverse situation to that previously reported and reflected a clear trend for a shift in the cropping pattern i.e. more focus towards ‘irrigated rice’ resulting from the increased availability of irrigation sources and development of new technologies (Alderman and Sahn, 1989; ADB, 2001; Tetens et al. 2003). Rural households were relatively more vulnerable than peri-urban immediately after the ‘monsoon rice’ season. This may be explained by lower earnings, at this time, whereas peri-urban households had greater access to other employment in the industrial sector that has grown up in urban areas (UNDP, 2005).

A high dependency on agriculture might be viewed as a key component of household vulnerability. In addition lack of education, skill, knowledge and information are the major factors associated with vulnerability, especially for poorer and non-pond households. Poor access to auction and large markets was a disadvantage for rural households as it reduced the options for disposing of their farm product (fish and vegetable).

In general, inadequate consumption of food items such rice, fish and vegetables often results in malnutrition and illness of the households irrespective of well-being, location and groups. Health status was similar between genders in all locations, while worse off households were found to suffer more than better off households during the change over in seasons perhaps due to their lower immunity to disease as a result of poorer nutrition than richer people.; this supports the findings of 'Helen Keller International' in Bangladesh (HKI, 2002). In Bangladesh food, nutrition and health factors are greatly influenced by the seasonal productivity (Chaudhury, 1980; Abdullah and Wheeler, 1985; Abdullah, 1989; Khander et. al. 2010), which are also an indicative of the extent of vulnerability as well as poverty especially in rural areas (Chaudhury, 1980; Messer, 1989; Tetens et al. 2003; Tetens and Thilsted, 2004). However, year-round cropping on pond dikes could reduce seasonal-induced vulnerability for households from varied socio-economic status and irrespective of location partly through smoothing of cash income, and makes it a highly acceptable food production system (Dercon and Krishnan, 1996).

5.5 Impacts of Pond-dike systems through smoothing income and consumption

Better off and worse off households' overall level of fish consumption was similar, although the better off consumed relatively more from their own production than other sources. The sale of higher value farmed fish by poorer households and purchase of cheaper small wild fish for their own consumption has been described before for Bangladesh (Thompson et al. 2006). In this study the average amount of fish consumed (83.1 g capita^{-1} day^{-1}) was almost double the national consumption figure (38.3 g capita^{-1} day^{-1}) regardless of wellbeing level (BBS, 2004; Bestari et al. 2005). It is noteworthy that this study was carried out only with the active integrated households, and that they are perhaps likely to produce and consume more fish than general pond owners. A study carried out in Kapasia sub-district of Bangladesh, however, reported very similar results (88 g capita^{-1} day^{-1}; mean of fish consumption of all socioeconomic level of households) (Thompson et al. 2005). The similar amount of fish purchased from the market by both groups seems surprising; however, poorer households probably bought cheaper, low quality fish. However, fish consumption increased significantly from 2000 to 2010 (FRSS, 2012), and seemingly beyond, among rural and urban households, while even extreme and moderate poor households had a small, but insignificant increase in consumption. (Bogard et al. 2017). Increased fish production over this period and an overall socio-geographic trend to more households moving out of poverty and increasing their purchase power probably explain these improvements.

The seasonality of consumption of pond fish can be explained by a number of factors. The lower consumption of fish in general between February and March (dry season) was possibly related to a lower availability of fish in ponds, wild stocks and/or due to lack of income to purchase fish. Lower consumption of pond fish by households at all locations between June and July was explained by greater availability and abundance of wild stocks at this time. This demonstrated how households change their fish consumption strategy depending on the situation. Income flows were also lower in these two months (Ahmed et al. 2005).

Similarly, in the months of September to November (winter and prior to the 'monsoon rice' harvest) consumption of non-leafy vegetables and pulses in the current study were relatively low perhaps due to constrained income during this period; the lower levels of consumption of key foods during this period point to this being a critical hungry gap (Abdullah and Wheeler, 1985; Ahmed et al. 2005). Consumption of leafy and non leafy vegetables, fish, milk, eggs and pulses were positively correlated with income which was also observed in another study carried out in Bamako, Mali (Camara, 2004) and also for fish consumption in Bangladesh (Dey et al. 2005).

The study indicated that households earned more from selling rice and vegetables between April to May and also from business which ultimately increased overall income. This supported the observations of Tetens et al. (2003), and Weinberger and Genova (2005). The on-farm supply of fish supported households' fish consumption better during the lowest income months (September to November), and were especially important to the worse off households during these months. This study showed that the household's own fish made up a large share of fish consumed irrespective of wellbeing and location. This contrasts with a study (carried out in Kapasia, Bangladesh) that households with fish ponds still bought more than half of the fish they consumed from the market (Thompson et al. 2005).

The mean income and expenses of the households' monitored in this study were 32.37 and 23.22 (US$ household^{-1} week^{-1}) respectively, which was very close to the mean national income 24.34 and expenses of 20.33 (US$ household^{-1} week^{-1}) (BBS, 2004). It was clear that poorer households spent a larger share (30%) of their income on purchasing food compared to better off (20%), which is a common scenario in most less developed Asian countries (Dey et al. 2005). This suggests that poorer households were more vulnerable than the better-off in terms of dependency on food purchases. The period of lower income and higher expenditures occurred at the same time, probably forcing them to borrow money. Household's borrowed relatively high amounts of money in March (prior to *the'irrigated* rice'harvest), June (low income month) and September (prior to the 'monsoon rice harvest) compared to other months of the year. During these periods households' lower incomes probably forced them to survive by reliance on credit. Expenditure was also relatively high in the months of March to June related to a need to invest in fish and rice inputs and higher labour expenses at the same time. In this period households spent more on fish culture (stocking, feeding and fertilizing ponds). However, this reflected households' higher dependency on 'credit' and 'interest free credit' for carrying out agricultural activities.

Finally, it could be concluded that pond-dike systems supported the households through smoothing income and food consumption flows throughout the year. The contribution of both fish and vegetable (around 40% of all food consumed) to the overall diet was substantial irrespective of location and well-being level. Furthermore, active pond-dike integration contributed significantly to household income. A similar contribution of fish (20%) and vegetable (5%) sales to both better off and worse off household income suggests equal importance of pond-dike system to households of different socio-economic level. A higher proportion of total income obtained from fish sales by periurban households (27%) compared to rural households (11%) reflected greater opportunity for commercialization through better marketing access. The contribution of farm raised fish in smoothing income and consumption was also confirmed by another study by Belton et al. (2012) where fish raised in homestead ponds represent a liquidable asset to reduce or avoid high interest debt burdens associated with 'irrigated rice' cultivation and purchase of rice for home consumption. These strategies may therefore function as a buffer against the threat of transient poverty. Most pond-dike farmers in the present study did produce a surplus consuming much less than they sold of both fish and vegetables in both rural and peri-urban sites. This suggests that even small homestead ponds can contribute to the wider food supply through such surpluses whilst supporting producer household susbsistence. Thus "quasi-peasant" forms of aquaculture (Belton et al. 2012) do contribute to reduced poverty and enhance food security in this part of Bangladesh. It is evident that the recent and rapid evolution of commercial aquaculture has focused on non-integrated intensive monoculture pangas and tilapia rather than improving yields of mixed carp polyculture integrated with other components of food production, based on locally available inputs. Jahan et al (2015) demonstrated that these latter systems are characterized by the highest benefit:cost ratios compared to more intensive systems and, because they remain the domain of poorer households, ensure the benefits of aquaculture remain widely distributed. Innovation is required for delivering interventions that support the use of higher nutrient inputs at scale to this very large group of potential beneficiaries.

Conclusion:

The study presents evidence that there is further potential for homestead pond-dike systems to contribute towards improved livelihoods of households irrespective of their wellbeing level. The contribution of both fish and vegetables to the overall diet was substantial irrespective of location and well-being level. Furthermore, active pond-dike integration contributed significantly to household income. The empirical analysis showed that as active households' income per capita increased, per capita expenditure on food purchases, agricultural labour and pond inputs also increased. On the other hand, consumption of various food items was linked to both income and availability. Households with homestead ponds met more than half of their fish consumption needs and the monitoring of active households suggested that these contributions to fish and vegetable consumption were most crucial during the lower income and least productive months. A higher proportion of total income from fish sales by periurban households compared to rural households reflected greater opportunity for commercialization through better market access. Finally, it could be concluded that pond-dike systems supported producer households through smoothing income and food consumption flows throughout the year. The similar level of contribution of fish and vegetable to the income of both better off and worse off households suggests that pond-dike systems have relevance to households across the community. However, the level of productivity from homestead pond-dike systems has remained realtively stagnant, a situation which could be further improved through relativley modest and available technological and capital intensification principally through enhanced quality and quantity of nutrient inputs. (Karim et al. 2016).

Our study supports the findings of Lewis (1997) and Karim (2016) who reported that a lack of knowledge rather than credit constrained poor households managing small ponds and ditches profitably for aquaculture in Bangladesh. The issue is often contradictory, however, as both money and information has been valued similarly by the participants of this study. So, it might be concluded that finance is one of the critical issues for the success of active integrated farming households but that the current mix of institutions providing credit are, at least to some extent, delivering credit where required. However, the study suggests that policies that aim to increase household income through intensifying existing low input-low output systems and off-farm activities would potentially be an effective mechanism to invest more on farming and eventually improve food security of the households, especially for the worse off households.

Acknowledgement: We would like to thank EC funded "The improved resource use efficiency in Asian integrated pond-dike systems (Pond Live)" project (ICA4-2001-10026) and DFID Aquaculture and Fish Genetics Research Programme for their financial contribution to the research. The opinions expressed herein are those of the authors and do not necessarily reflect the views of EC and DFID. The authors would like to thank Dr. Trevour Telfer, University of Stirling, Scotland, UK and Dr. Md. Abdul Wahab, Bangaldesh Agricultural University, Bangladesh for their inputs to the study design.

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Table 1. Primary occupation (numbers of household heads) by systems and well-being and location

Criteria	Groups	Agriculture[1]	Service[2]	Labour[3]	Business[4]	Petty business[5]	Fish culture	Total
Rural	Active	37(77)	4(8)	1(2)	3(6)		3(6)	48(100)
	Passive	27(84)	2(6)	2(6)	0(0)		1(3)	32(100)
	Non-pond	19(59)	3(9)	6(19)	4(13)		0(0)	32(100)
Rural total		83(74)	7(6)	9(8)	4(4)		9(8)	112(100)
Peri-urban	Active	21(60)	3(9)	1(3)	3(9)	5(14)	2(6)	35(100)
	Passive	24(69)	5(14)	3(9)	1(3)	0(0)	2(6)	35(100)
	Non-pond	12(52)	3(13)	6(26)	2(9)	0(0)	0(0)	23(100)
Peri-urban total		57(61)	11(12)	10(11)	6(6)	5(5)	4(4)	93(100)
Better off	Active	29(71)	5(12)		4(10)		3(7)	41(100)
	Passive	24(80)	4(13)		2(7)		0(0)	30(100)
	Non-pond	15(63)	4(17)		5(21)		0(0)	24(100)
Better off total		68(72)	13(14)		11(12)		3(3)	95(100)
Worse off	Active	29(69)	2(5)	2(5)	1(2)	6(14)	2(5)	42(100)
	Passive	27(73)	3(8)	5(14)	1(3)	1(3)	0(0)	37(100)
	Non-pond	16(52)	0(0)	12(39)	0(0)	3(10)	0(0)	31(100)
Worse off total		72(65)	5(5)	19(17)	2(2)	10(9)	2(2)	110(100)
Total	Active	58(70)	7(8)	2(2)	5(6)	6(7)	5(6)	83(100)
	Passive	51(76)	7(10)	5(7)	3(4)	1(1)	0(0)	67 (100)
	Non-pond	31(56)	4(7)	12(22)	5(9)	3(5)	0(0)	55 (100)
Total		140(68)	18(9)	19(9)	13(6)	10(5)	5(2)	205(100)

(Figures in the parentheses area percentage) (Involvement in rice and vegetable cultivation in own managed land [1]; part time or full time job in government/non-government organization[2]; off-farm/on-farm agri/non-agricultural labour[3]; buying and selling agricultural and non-agricultural commodities with substantial amount of money investment[4]; Small stationeries, shops, invest small amount of money and get quick return, for instance retailing and selling fish, vegetable etc[5]).

Table 2: Level of education, land ownership pattern, access to credit by group, well-being level and location

Location		Peri-Urban								Peri-urban total	Rural								Rural total	Grand total
Wellbeing		Better off				Worse off					Better off				Worse off					
Variables	Disaggregated by	Pond-dike (Active)	Pond-dike (Passive)	Non-pond	Sub-total	Pond-dike (Active)	Pond-dike (Passive)	Non-pond	Sub-total		Pond-dike (Active)	Pond-dike (Passive)	Non-pond	Sub-total	Pond-dike (Active)	Pond -dike (Passive)	Non-pond	Sub-total		
% distribution of educational level of households Head[I]	Illiterate	11(2)	7(1)	11(1)	10(4)	35(6)	40(8)	73(11)	48(25)	31(29)	22(5)	25(4)	31(5)	25(14)	28(7)	82(14)	81(13)	59(34)	42(48)	37(77)
	Primary	39(7)	21(3)	44(4)	34(14)	29(5)	25(5)	20(3)	25(13)	29(27)	35(8)	25(4)	44(7)	35(19)	40(10)	6(1)	19(3)	24(14)	29(33)	29(60)
	Junior	-	7(1)	-	2(1)	24(4)	15(3)	-	13(7)	9(8)	-	13(2)	13(2)	7(4)	4(1)	-	-	2(1)	4(5)	6(13)
	SSC	22(4)	43(6)	22(2)	29(12)	12(2)	15(3)	-	10(5)	18(17)	35(8)	25(4)	6(1)	24(13)	12(3)	6(1)	-	7(4)	15(17)	17(34)
	HSC	11(2)	0	11(1)	7(3)	-	5(1)	-	2(1)	4(4)	-	13(2)	-	4(2)	-	-	-	-	2(2)	3(6)
	Graduation	17(3)	21(3)	11(1)	17(7)	-	-	7(1)	2(1)	9(8)	9(2)	-	6(1)	5(3)	16(4)	6(1)	-	9(5)	7(8)	8(16)
% distribution of households land ownership[I]	Own	83(141)	88(89)	88(66)	86(296)	88(128)	78(90)	36(20)	75(238)	81(534)	85(21)	82(10)	72(63)	82(376)	74(14)	60(55)	33(15)	65(215)	75(591)	77(1125)
	Leased in	2(3)	12(7)	7(9)	6(19)	9(13)	8(9)	59(33)	17(55)	11(74)	0	0	14(12)	3(13)	20	16(15)	31(14)	20(68)	10(81)	11(155)
	Leased out	9(16)	0(4)	4	6(20)	0	0	0	0	3(20)	11(1)	14	9(8)	12(53)	0(39)	4(4)	29(13)	5(17)	9(70)	6(90)
	Mortgaged in	4(6)	0	0	2(6)	0	2(2)	5(3)	2(5)	2(11)	0(28)	0(17)	5(4)	1(4)	1	0	7(3)	1(4)	1(8)	1(19)
	Sharing	2(3)	0(1)	1	1(4)	3(5)	12(14)	0	6(19)	3(23)	3(8)	4(5)	0	3(13)	6(11)	20(18)	0	9(29)	5(42)	4(65)
Land ownership (ha/HH)[II]	Own	1.25 (0.71)	1.70 (2.26)	1.09 (0.62)	1.36 (1.41)	0.58 (0.40)	0.46 (0.39)	0.16 (0.36)	0.43 (0.41)	0.84 (1.08)[a]	.03 (1.49)	1.88 (1.45)	0.92 (0.85)	1.66 (1.38)	0.66 (0.50)	0.39 (0.34)	0.22 (0.41)	0.48 (0.46)	1.08 (1.19)[a]	0.97 (1.15)
	Leased in	0.03 (0.12)	0.30 (1.01)	0.20 (0.43)	0.15 (0.61)	0.22 (0.49)	0.11 (0.28)	0.54 (0.58)	0.25 (0.47)	0.21 (0.54)a	0.00 (0.01)	0.00 (0.00)	0.36 (0.74)	0.11 (0.43)	0.27 (0.40)	0.31 (0.50)	0.26 (0.49)	0.28 (0.44)	0.19 (0.44)a	0.20 (0.49)
	Leased out	0.36 (0.80)	0.28 (1.01)	0.00 (0.00)	0.26 (0.79)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.12 (0.54)a	0.42 (1.00)	0.67 (0.98)	0.14 (0.40)	0.41 (0.87)	0.00 (0.00)	0.06 (0.24)	0.15 (0.49)	0.05 (0.26)	0.23 (0.66)a	0.18 (0.61)
	Mortgaged in	0.05 (0.15)	0.00 (0.00)	0.00 (0.00)	0.02 (0.10)	0.00 (0.00)	0.02 (0.11)	0.01 (0.03)	0.01 (0.07)	0.02 (0.09)a	0.00 (0.00)	0.00 (0.00)	0.22 (0.72)	0.07 (0.40)	0.01 (0.03)	0.00 (0.00)	0.08 (0.23)	0.02 (0.11)	0.04 (0.29)a	0.03 (0.22)
	Sharing	0.02 (0.08)	0.00 (0.01)	0.00 (0.00)	0.01 (0.05)	0.05 (0.14)	0.07 (0.12)	0.00 (0.00)	0.04 (0.11)	0.03 (0.09)a	0.05 (0.09)	0.05 (0.09)	0.00 (0.00)	0.03 (0.07)	0.10 (0.29)	0.20 (0.49)	0.00 (0.00)	0.11 (0.34)	0.07 (0.25)a	0.05 (0.20)
% of households loan taken	No Loan	45(9)	40(6)	78(7)	50(22)	0	26(6)	31(5)	18(11)	32(33)	19(6)	22(4)	22(4)	21(14)	9(3)	28(5)	33(6)	20(14)	21(28)	25(61)
	Loan WI[III]	25(5)	47(7)	22(2)	32(14)	52(11)	48(11)	50(8)	50(30)	42(44)	42(13)	44(8)	33(6)	40(27)	48(16)	56(10)	44(8)	49(34)	45(61)	44(105)
	Loan WoI[IV]	30(6)	13(2)	0	18(8)	48(10)	26(6)	19(3)	32(19)	26(27)	39(12)	33(6)	44(8)	39(26)	42(14)	17(3)	22(4)	30(21)	35(47)	31(74)
Amount of loan taken (US$/HH)[II]	Loan WI[III]	84(75)	247(290)	89(-)	166(218)	163(109)	157(263)	117(135)	148(181)	154 (191)[a]	357(203)	220(224)	146(118)	270(208)	152(181)	142(105)	75(89)	131(143)	192(187)[a]	176(189)
	Loan WoI[IV]	103(129)	13(13)		80(117)	67(60)	131(252)	60(57)	86(144)	84 (135)[a]	120(106)	115(126)	85(113)	108(109)	96(90)	68(96)	32(17)	80(83)	95(98)[a]	91(112)
	Loan total	94(103)	195(272)	89(-)	135(189)	117(100)	148(251)	101(119)	124(169)	127 (174)[a]	243(201)	175(190)	111(115)	190(184)	126(146)	125(104)	61(75)	111(125)	150(161)[a]	141(166)
% sources of loan[I]	Bank	20(2)	57(5)	64(1)	41(8)	29(7)	12(2)	19(2)	23(11)	28(19)	25(9)	40(5)		20(14)	21(9)	45(8)	13(2)	23(19)	22(33)	24(52)
	NGO	15(1)	13(1)		12(2)	17(5)	1(1)	9(2)	12(8)	12(10)		7(1)		2(1)	2(1)	20(2)	24(2)	8(5)	5(6)	8(16)
	Family					3(2)	1(1)	0	2(3)	2(3)		2(1)		(1)		16(2)	4(1)	3(3)	2(4)	2(7)
	Neighbors	34(6)	31(3)	36(1)	33(10)	50(14)	86(15)	72(9)	62(38)	55(48)	69(18)	26(5)	76(12)	62(35)	52(19)	12(2)	54(6)	47(27)	54(62)	55(110)
	Relatives	31(2)			14(2)					3(2)	7(1)	24(2)	24(2)	16(5)	25(6)	8(1)	5(1)	19(8)	18(13)	11(15)

([I]Figures in the parentheses are number of respondents) ([II]Figures in the parentheses are standard deviations) ([III]WI-Without Interest; [IV]WoI- Without Interest)
(a= no diff./non-sig. P>0.05)

Table 2. Inputs used (number of households/year) in the ponds by location, well-being and groups

Criteria	Fish seed	Rice bran	Quick lime	Oil cake	Organic fertilizers	Inorganic fertilizers	Insecticide	Wheat bran	Water	Grass
Rural	**70 (89)**	**66 (84)**	**53 (67)**	**44 (56)**	**44 (56)**	**40 (51)**	**9 (11)**	**2 (3)**	**6 (8)**	
Peri-urban	**55 (83)**	**50 (76)**	45(68)	**40 (61)**	**27 (41)**	**29 (44)**	**5 (8)**	**8 (12)**	**4 (6)**	**2 (3)**
Better off	**59 (88)**	**56 (84)**	**49 (73)**	**42 (63)**	**36 (54)**	**36 (54)**	**11 (16)**	**5 (7)**	**7 (10)**	**2 (3)**
Worse off	**66 (85)**	**60 (77)**	**49 (63)**	**42 (54)**	**35 (45)**	**33 (42)**	**3 (4)**	**5 (6)**	**3 (4)**	
Active	**67 (85)**	**66 (84)**	**53 (67)**	**50 (63)**	**44 (56)**	**45 (57)**	**11 (14)**	**9 (11)**	**7 (9)**	**2 (3)**
Passive	**58 (88)**	**50 (76)**	**45 (68)**	**34 (52)**	**27 (41)**	**24 (36)**	**3 (5)**	**1 (2)**	**3 (5)**	
Total average	**125 (86)**	**116 (80)**	**98 (68)**	**84 (58)**	**71 (49)**	**69 (48)**	**14 (10)**	**10 (7)**	**10 (7)**	**2 (1)**

(Figures in the parentheses are percentage of households)

Table 3. Fish seed stocking frequency (times/year)

Location	Well-being	Mean
Rural	Better off (n=32)	2.75(2.68)
	Worse off (n=38)	2.08(1.82)
Peri-urban	Better off (n=27)	1.56(0.80)
	Worse off (n=28)	1.82(0.82)
Total average	Better off (n=59)	2.20(2.12)
	Worse off (n=66)	1.97(1.48)

(Figures in the parentheses are standard deviation)

Table 4. Production (kg/ha and kg/hh) of fish and vegetables by well-being and groups

Criteria	Fish			Vegetable		
	Kg/ha	Kg/hh	n	Kg/ha	Kg/hh	n
Better off	2,634.11(2,423.02)[a]	222.78 (248.43)[a]	68	4,779.75(4,606.78)[a]	466.13(763.37)[a]	63
Worse off	1,585.22 (1,235.71)[b]	113.53(112.72)[b]	78	4,232.43(4,315.63)[a]	364.69(688.11)[b]	65
Rural	1,954.30 (1,919.08)[a]	127.98(155.23)[b]	80	4,155.79(4,334.94)[a]	402.61(709.96)[a]	71
Peri-urban	2,208.23 (1,981.20)[a]	208.58(228.99)[a]	66	4,921.87(4,592.27)[a]	428.46(748.52)[a]	57
Active	2,186.52 (1,969.02)[a]	175.33 (209.03)[a]	79	5,389.57(5,023.74)[a]	468.12(783.84)[a]	83
Passive	1,930.27 (1,921.31)[a]	151.54(179.15)[b]	67	2,750.66(2,506.18)[b]	345.70(715.13)[b]	30
Non-pond				3,132.50(2,462.32)[b]	256.53(243.06)[b]	15
Total average	2,069.88 (1,944.93)	164.41(195.59)	146	4,499.62(4,450.84)	414.21(724.71)	128

(Figures in the parentheses are standard deviation) (Mean values followed by different superscript letters indicate significantly different ($P < 0.05$) based on ANOVA)

Table 5. Water sources for irrigating vegetables by location, well-being and groups

Criteria	Pond	STW[1]	DTW[2]	Beel[3]	Total
Rural (n=54)	44(81)	19(35)	2(4)	3(6)	68(126)
Peri-urban (n=45)	42(93)	2(4)	5(11)	0	49(109)
Better off (n=47)	41(87)	9(19)	2(4)	2(4)	54(115)
Worse off (n=52)	45(87)	12(23)	5(10)	1(2)	63(121)
Active (n=66)	66(100)	13(20)	2(3)		80(121)
Passive (n=25)	19(76)	4(16)	3(12)	3(12)	29(116)

Non-pond (n=8)	2(25)	4(50)	2(25)		8(100)
Total average (n=99)	86(87)	21(21)	7(7)	3(3)	117(118)

Numbers of (multiple) responses (Figures in the parentheses are percentage) ([1]STW-Shallow Tube Well, [2]DTW- Deep Tube Well and [3]Beel-a lake-like wetland with static water)

Table 6: Source of fish consumed (household wise)

Criteria	**Culture**	**Market**	**Wild**	**Rice fish (natural)**	**Rice fish (culture)**
Rural	59 (63)	39 (42)	19(20)	2 (2)	2 (2)
Peri-urban	60 (54)	70 (63)	31(28)	3 (3)	0
Better off	62(65)	52 (55)	22 (23)	4 (4)	1 (1)
Worse off	57 (53)	57(52)	28 (25)	1 (1)	1 (1)
Active	68 (82)	41(49)	31(37)	1 (1)	1 (1)
Passive	51(76)	29 (44)	9 (13)	1 (1)	1 (1)
Non-pond		46 (84)	10 (18)	3 (5)	0
Total	**119 (58)**	**109 (54)**	**50 (24)**	**5 (2)**	**2 (1)**

Number of (multiple) responses (Figures in the parentheses are percentage of households)

Table 7: Seasonal trends in health status, food and financial deficit months by well-being level

Wellbeing level		**Summer (Mar to Jun)**	**Moonsoon (Jun to Oct)**	**Winter (Oct to Mar)**
Worse-off	Frequency of diseases	CH	L	CH
	Level of food and financial deficiency	CL	L	CH
Better- off	Frequency of diseases	CL	L	CL
	Level of food and financial deficiency	CL	L	L

Comparatively high (CH), comparatively low (CL), Low (L)

Table 8: Average on-farm and non-farm income (US$/household) and (US$/capita) by location, well-being and groups

CR.	**Group**	**On-farm (US$/hh)**	**Non-farm (US$/hh)**	**Total**	
				(US$/hh)	**(US$/Capita)**
Better off	Active (n=41)	1103.85(740.80)^{a}	274.98(355.95)^{b}	1378.83(829.78)^{a}	248.13 (177.72)^{a}
	Passive (n=30)	1236.04(976.56)^{a}	272.07(469.98)^{b}	1508.11(1005.01)^{a}	237.75 (156.12)^{a}
	Non-pond (n=24)	608.20(394.84)^{b}	398.56(383.24)^{a}	1006.76(500.70)^{b}	178.72 (89.19)^{b}
	Mean (n=95)	1020.38(791.93)	305.28(401.21)	1325.66(838.91)	227.32 (154.06)
Worse off	Active (n=42)	533.11(326.40)^{a}	129.84(180.45)^{b}	662.96(344.94)^{a}	109.30 (55.52)^{a}
	Passive (n=37)	404.29(258.99)^{a}	236.25(329.07)^{a}	640.54(416.48)^{a}	122.64 (96.18)^{a}
	Non-pond (n=31)	191.41(194.94)^{b}	215.63(193.99)^{a}	407.03(268.13)^{b}	76.50 (62.64)^{b}
	Mean (n=111)	393.48(303.07)	189.81(246.33)	583.29(366.37)	104.54 (75.09)
Mean	Active (n=83)	815.04(635.12)^{a}	201.54(288.82)^{b}	1016.58(724.58)^{a}	177.88 (147.73)^{a}
	Passive (n=67)	776.71(793.27)^{a}	252.29(395.52)^{a}	1029.00(852.85)^{a}	174.18 (138.14)^{a}
	Non-pond (n=55)	373.28(361.98)^{b}	295.45(303.06)^{a}	668.73(486.64)^{b}	121.10 (90.48)^{b}
	Mean (n=205)	683.99(660.50)	243.32(331.55)	927.32(730.56)	161.44 (133.10)

(Figures in the parentheses are standard deviation; CR.-Criteria) (Mean values followed by different superscript letters indicate significantly different ($P < 0.05$) based on ANOVA)

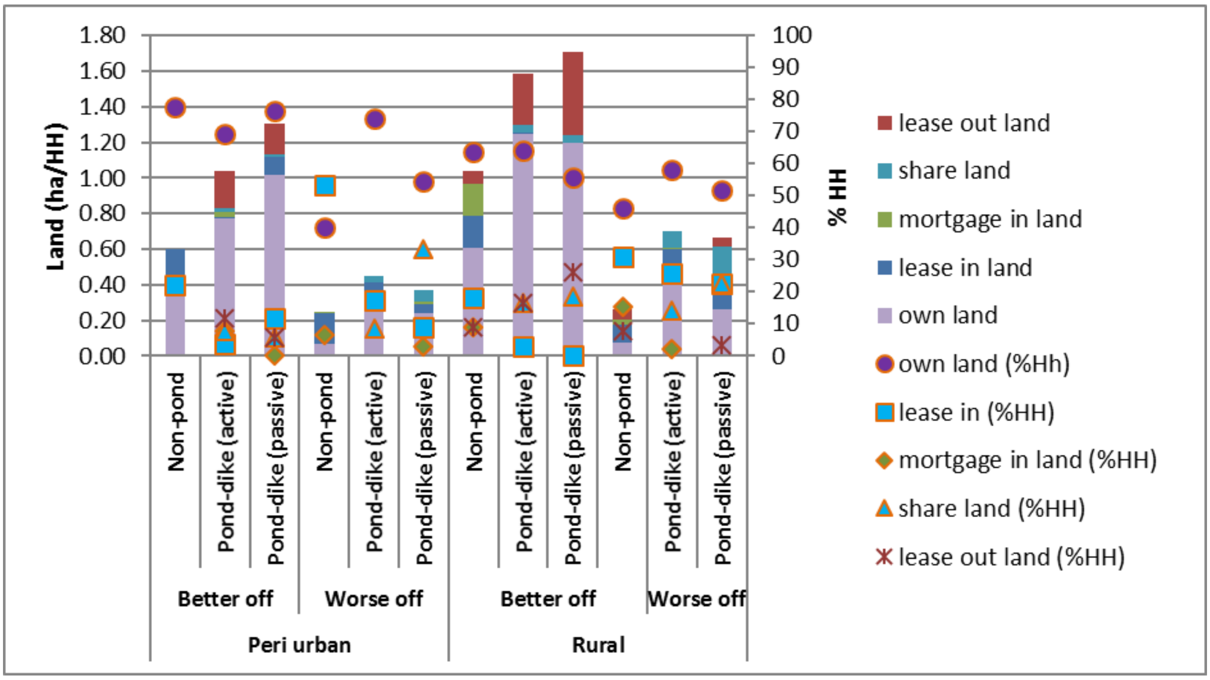

Figure 1. Own land ownership pattern by well-being and groups

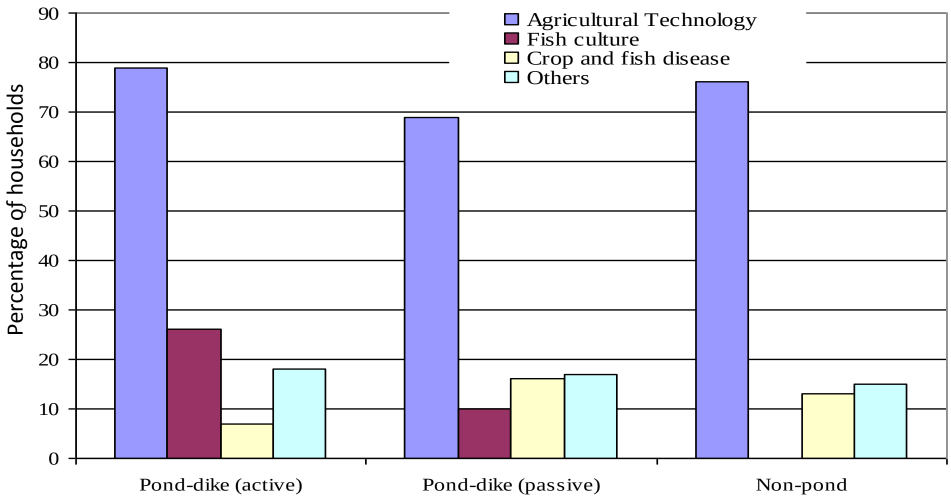

Figure 2. Types of information received by the groups

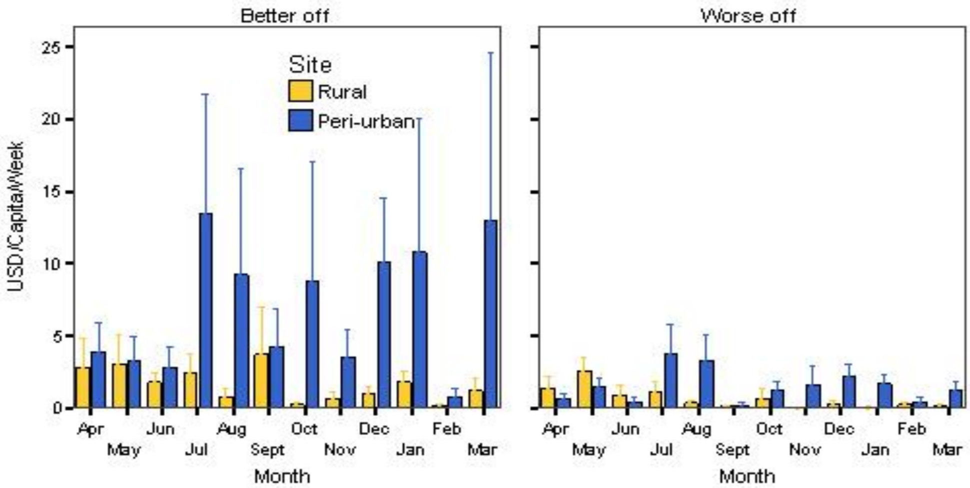

Figure 3: Income (US$/capita/week) from selling fish by location and well-being

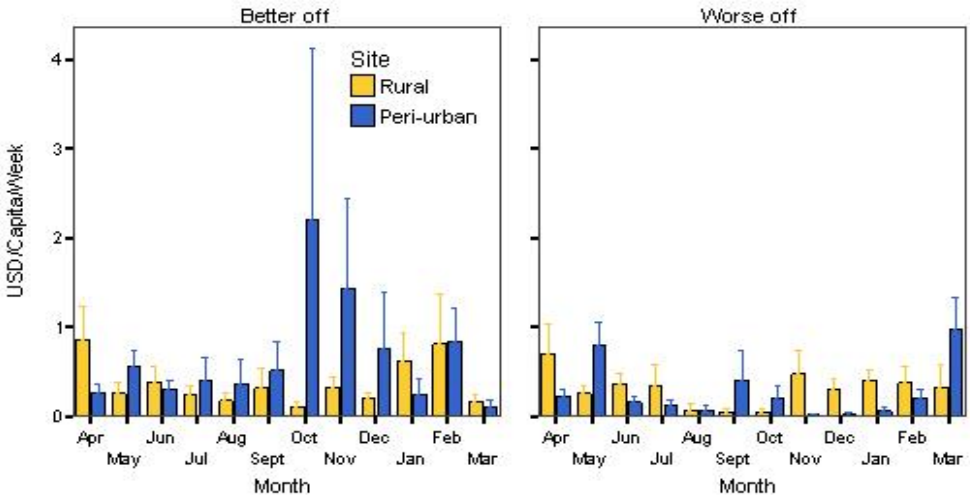

Figure 4: Income (US$/capita/week) from vegetable selling by location and well-being

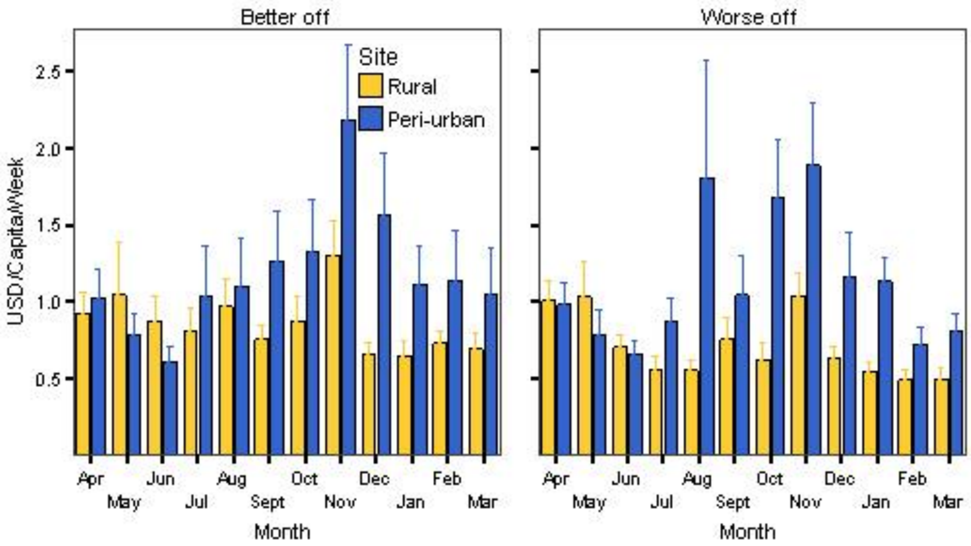

Figure 5. Food purchase expenses (US$/capita/week) by location and well-being

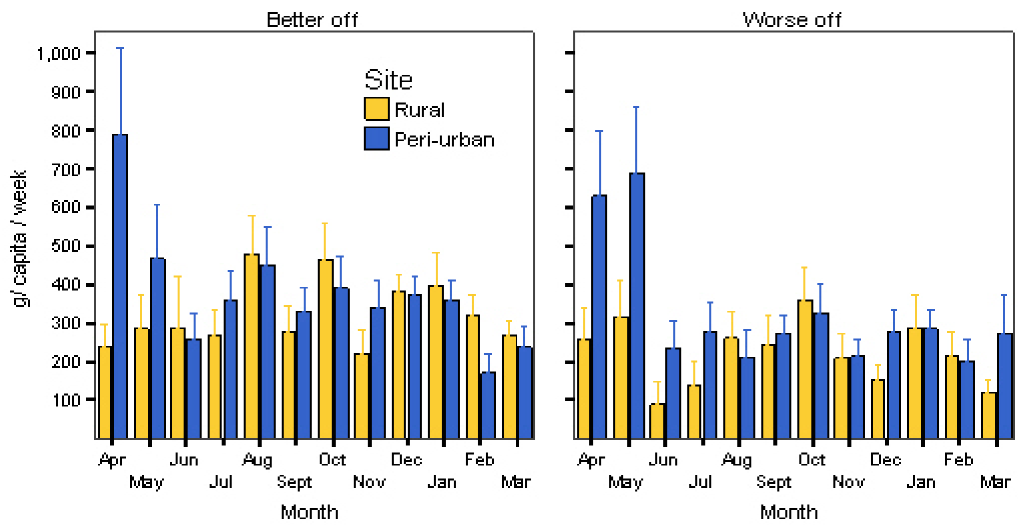

Figure 6: Fish consumption (g/capita/week) from farm source by well-being