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Full Length Research Paper

Improving dairy production in Bangladesh: Application of integrated agriculture and ecohealth concepts

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This work investigates the management and veterinary health interventions for dairy cattle in an integrated agricultural system practiced by 1,500 poor villagers living in 300 households in the Jamuna River Chars (Bogra, Jamalpur and Sirajganj Districts) of Bangladesh. The average production after one lactation for indigenous cattle was 2.53 L/cow/day (229 day lactation) and for cross-bred cattle was 7.72 L/cow/day (270 day lactation) respectively. The services per conception were 1.38 and 1.97 respectively. The dairy profit per lactation (Taka/cow) in Bogra, Jamalpur and Sirajganj respectively was 2320, 3582, and 2076; ratio of milk revenue to feed costs was 1.76, 2.83, and 1.60; returns on investment was 1.06, 0.92 and 1.07. The strong economic equity as well as the land holdings of the studied households may have been a factor that determined which households were able to select dairy cattle. The participants in this research requested for further management training, delivery of health services and market development. The research reflects five of the six pillars of ecohealth (transdisciplinarity, community participation, gender and economic equity, sustainability, and knowledge for action), but failed to assess complexity and systems thinking. Further research is needed to support the suggestion that dairy production provides more than enough economic support to the Chars community since it sustains resilience in a vulnerable ecosystem.

Key words: Bangladesh, ecohealth, food security, dairy, complexity.

INTRODUCTION

Bangladesh is a low-lying densely populated country of more than 150 million people, 75% of whom live in rural villages, with a rural poverty rate of 63% (UNDP, 2008; World Bank, 2006). Although the country is rapidly industrializing, 61% of Bangladeshis still earn their main income from some form of traditional agriculture; thus, most villages are built around farms. Rice is the principal crop grown; most villages also engage in some form of aquaculture, horticulture, and/or livestock raising. Land is the primary constraint to agriculture, and thus an integrated approach has been advocated although many efforts have not been sustainable. This has been due mainly to the top down approach used which often ignores marketing of output produced, rather than development from an understanding of the needs and interests of the primary stakeholders, the villagers themselves. As a result, efforts may be abandoned, leaving villagers once again in a state of food insecurity and facing increasing poverty. An example of successful technical integration has been in the villages of Dauki and Damgaon, Mymensingh district (known as the Dauki-Damgaon village community or DDVC), where a research team from Bangladesh Agricultural University (BAU) has been conducting participatory research and demonstrating the integrated cultivation of rice, fish, prawns, vegetables and small-scale livestock. The cycle of agricultural integration in DDVC continues year round

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varying with the rice growing and flood season. In the dry season, rice fields are converted to fish/prawn ponds; vegetables are grown on raised dykes and small-scale livestock are kept around households. This ecosystem-friendly concept has not only been technically successful for the farmers resulting in more efficient production, but it has also ensured the food and nutritional security for the immediate villages and other villages in the region.

Field reports show that gross economic profits more than tripled, women's employment increased 13%, and energy intake in Kcal/caput/day increased 51% (Hossain, 2005, 2000), raising hundreds of families above the poverty line. Similar success was recorded for education, housing and access to medical services. Other researchers have found similar success from integrated farming practices, particular in terms of elevating household incomes and improving efficiency of production (Wahab et al., 2005). Opportunities for applying these success stories were identified in other areas of Bangladesh, although the challenges due to environmental and economic constraints were considerably greater. In the chars[1] area of northern Bangladesh where poverty rates are up to three times as high as the national average, three communities were identified (described as follows) where an integrated agricultural development approach could be applied to improve livelihoods. This paper describes preliminary results of work to improve small scale dairy reproductive health and production in those areas and reflects on characteristics of the study that constitute an ecosystem approach to health management (ecohealth) through integrated agricultural development in order to increase the likelihood of sustainable results. Conclusions are drawn with regard to full application of an ecohealth approach including analysis of complexity and systems thinking, two concepts the authors suggest were missing from their original research.

The use of an ecohealth approach (Lebel, 2003) has been well documented in other developing countries, including livestock production systems (Joshi, 2006; Okello-Onen et al., 2012). Addressing economic and social development of villages in these areas is consistent with the goals of the Bangladesh National Livestock Development Policy (Hall, 2005), the Agriculture and Rural Development section of the Bangladesh Poverty Reduction Strategy Paper (2005), the National Food Policy of Bangladesh (2004) and the National Rural Development Policy of Bangladesh (2001). Three key needs of the Chars of northern Bangladesh specifically highlighted in these policy documents are addressed by this project. They are: 1) Development of an integrated herd health system for small-scale dairying; 2) development of a milk marketing system; and 3) sustainable development through a rising tide of economic activity.

MATERIALS AND METHODS

Selection of participants and projects

This study began in May 2009 and it is still ongoing. The dairy production data reported in this paper are from the first lactation data collected by the villagers participating in the study. Faculty members of Bangladesh Agricultural University and local non-government organizations (NGOs) working in Bangladesh in Sariakandi Upazila[2] of Bogra District, Islampur Upazila of Jamalpur District and Belkuchi Upazila of Sirajganj District developed an integrated agricultural development programme designed to improve the livelihoods of low income members of villages in those areas. All three Upazilas are located proximal to the Jamuna River; villages are located within the Chars regions where severe flooding and soil erosion occurs annually and where contrasting severe drought occurs occasionally. Services such as health care, electricity and education are rarely available. The total sample area includes more than one million people living in roughly 175,000 households[3]. Few rural households achieve more than poverty levels of income, estimated at less than $400 per working person per year (Bangladesh Bureau of Statistics, 2001). More than 60% of residents live below the poverty line, functional literacy is less than 34% and life expectancy at birth is less than 60 years. Roughly, 1500 people were included to participate using a random sample of 300 poor households from twelve villages in the areas in which the NGOs were already operating. Criteria for inclusion in the study were jointly established by the NGOs delivering the support activities (training, workshops, etc.), villagers in the communities and BAU faculty. High level criteria for selection included low household income (poverty as defined by the Government of Bangladesh), children living in the household, engagement in some sort of agricultural activities and previous village level experience with some form of microcredit.

Many of the non-selected households were already participants of similar NGO development projects operating in the area, most principally the highly successful Char Livelihoods Programme (CLP) of UK-DFID (CLP, 2011) which provides a wide range of other support activities including some livestock development components such as market development and feeding management.

Households in the study reported here were offered the option of a development package that included improvement of existing and new livestock including reproductive health services and basic dairy cow management or that included other options including vegetable production. All options included other support including training in small business management, market access development, household financial management, and educational components for children and adults. Of the selected participants, 718 chose livestock projects in which to participate and 716 chose non-livestock projects such as vegetable production. Agricultural demographics of the villages and participants are included in Table 1. The study began in November 2009 and is still ongoing. The dairy production data reported in this paper are from the first lactation data collected by the villagers participating in the study.

[1] The Chars are islands of land in the middle of the rivers in northern Bangladesh and are some of the most vulnerable regions of the country. A few hundred chars exist in Bangladesh, home to some 3.5 million people. Char-dwellers migrate up to 40 or 50 times in a lifetime due to the seasonal extremes of weather. The main source of livelihood is relief aid according to several NGOs working in the Chars regions.

[2] An Upazila is a political boundary delineation in Bangladesh similar to a county category. The administrative structure from largest to smallest consists of Divisions, Districts, Upazilas or Thanas, Union Porishods (similar to wards) and lastly Graam or Paara (similar to villages).

[3] The last official census was conducted in 2001, but population data are unofficially estimated by NGOs and other development groups working in the target regions.

Table 1. Agricultural characteristics of Bangladesh villagers in livelihoods study.

Variable	Agricultural activity chosen	
	Dairy	Non-dairy
Number of households	150	150
Number of participants	718	716
Households owning 5 decimals[1] of land	93	44
Households owning 10 decimals or more of land	21	7
Households able to cultivate 10 decimals of land	67	n.a[2]
Households able to cultivate 20 decimals of land	42	n.a.
Average number of cattle per household	3.4	0.1
Average number of sheep and goats per household	3.1	2.7
Average number of poultry per household	3.7	3.5
Households with access to drinking water (%)	72.0	54.2
Households with access to sanitation (%)	70.2	46.9
Self declared household daily income (taka)[3]	108.3	54.0
Households with a cell phone	78	6
Households with a radio	22	0
Households with a bicycle	19	2

[1]One decimal of land = 0.01 acres = 0.004 ha.
[2]These data were not available.
[3]One US dollar = 70.5 Bangladeshi Taka as of January 01, 2011.

RESULTS

The data that describe the agricultural characteristics of the villagers in the livelihoods study reported in this paper (Table 1) provide some interesting insights to the demographic differences between the participants who chose dairy cattle and the participants who chose other agricultural activities. When compared to non-dairy participants, clearly the dairy participants own or have access to larger pieces of land, earn twice the daily household income and are more likely to own purchased consumables such as cell phones. Slightly more than half of households reported that women were the primary attendants of livestock. Because the data were collected at the start of the study, they are not indicative of the impact on household income due to interventions in dairy health or management. These data are still being gathered. It is also noteworthy that the dairy households reported considerably higher access to drinking water and sanitation. While these and other data indicate both groups are below the poverty level for that region of Bangladesh, the statistics from Table 1 present a profile of the dairy households that suggests they are 'less' poor than the non-dairy households. In Bogra District, data were also gathered from a sample of households that received basic dairy management and animal health training for 380 indigenous dairy cattle and 839 crossbred[1] cattle (Table 2). Because of the obvious genetic differences paired value differences were not tested for significance, but the data are valuable to provide a picture of the level of dairy production achieved by the villagers who had indigenous or crossbred dairy cattle in Bogra.

Crossbred cattle produced three times the daily milk production compared to indigenous cattle, the age at first service was five months sooner, age at first calving occurred six months sooner, lactation length was a month and a half longer and calf birth weights were 25% heavier. In contrast, services per conception for the crossbreds were 43% higher than the indigenous cattle and the calving interval was about one month longer.

Economic data are reported in Table 3 for the dairy producers of Bogra, Jamalpur and Sirajganj districts using indigenous cattle. Differences of feed costs between districts, milk and manure revenues (and thus dairy profit), ratio of milk revenue to feed costs and returns on investment were significant between districts. Purchase prices of cattle were similar across districts as were veterinary costs. Although, the ratio of milk revenue to feed costs for Jamalpur was 61 and 77% greater than for Bogra and Sirajganj respectively, return on investment (ROI) was conversely 13 and 14% less respectively. As well, ROI for Jamalpur was unacceptably below one, while ROI for Bogra and Sirajganj were just above one.

Finally, dairy producers owning indigenous cattle were asked about year-round access to milk markets. Produ cers reported that dairy middlemen were available to take

[1]Indigenous cattle are crossed with some degree of purebred Holstein-Friesian (HF) cattle, although breeding records are not detailed enough to know precise parent lines. Much of the dairy artificial insemination industry imports purebred HF semen from North America and Europe, resulting in readily identifiable phenotypic characteristics that are in contrast to the indigenous *Bos indicus* and *Bos taurus* cattle.

Table 2. Agricultural characteristics post-training from dairy cow owners in Bangladesh.

Variable	Indigenous breed[2]	Cross bred
Number of dairy cattle	380	839
Body weight (kg)	185.38(19.95)	280.94[3](31.86)
Milk production (L/day)	2.53(0.83)	7.72(2.22)
Age at first service (months)	27.17(2.59)	22.15(3.10)
Services per conception	1.38(0.43)	1.97(0.61)
Age at first calving (months)	37.15(3.05)	31.87(3.55)
Calving to first service interval (days)	128.53(25.15)	129.52(27.80)
Gestation length (days)	277.63(3.98)	277.38(4.09)
Dry period (days)	135.02(22.72)	132.05(21.69)
Lactation length (days)	229.44(27.55)	270.16(21.69)
Calving interval(days)	428.26(41.81)	455.04(36.59)
Calf birth weight (kgs)	16.57(2.09)	20.77(2.04)

[2]No bovine reproductive health assistance was provided to this group.
[3]Paired value differences were not tested for significance due to the obvious strong environmental difference (breed) between the two groups of cattle.

Table 3. Economic variables for Bangladeshi dairy cattle in livelihoods study.

Variable	District		
	Bogra	Jamalpur	Sirajganj
Number of dairy cattle	109	115	153
Purchase price of cow (Taka/cow)[2]	13,560.73(1386.40)	13,800.13(1414.38)	14,079.22(1709.04)
Feed costs (Taka/cow)	4535.26[a](1903.03)	3799.52[d](2496.61)	5079.96[a,d](5403.63)
Veterinary costs (Taka/cow)[3]	340.00(297.97)	309.17(304.20)	348.04(341.89)
Milk revenue (Taka/cow)	6543.03[a](4750.07)	7462.09[a](6469.00)	6942.28[a](7361.07)
Manure revenue (Taka/cow)	726.61[c](371.61)	450.21[a,c](348.60)	664.28[a](591.29)
Dairy profit (Taka/cow)[4]	2319.52[a](4982.62)	3581.78[a](6388.75)	2076.24[a](4974.55)
Ratio of milk revenue to feed costs	1.76[a](1.43)	2.83[a](3.39)	1.60[a](1.68)
Returns on investment[5,6]	1.06[b](0.74)	0.92[c](0.60)	1.07[b,c](1.10)

[2]All financial figures are in Bangladesh Taka. One US dollar = 70.5 Bangladeshi Taka as of January 01, 2011.
[3]Veterinary costs include deworming, vaccines and cost of para-veterinary services.
[4]Profit calculated as [(Milk revenue + Manure revenue) – (purchase price + feed costs + veterinary costs)].
[5]Returns on investment calculated as [(value of milk revenue + manure revenue + cow value + calf value) – (Purchase price + feed costs + veterinary costs)]/purchase price.
[6]For ROI cow and calf values at the end of the study were included whether or not producers sold their cow or calf at the end of the lactation.
[a,d]Significant difference of means within row ($p < 0.01$); [b]Significant difference of means within row ($p < 0.1$) and [c]Significant difference of means within row ($p < 0.05$).

milk during high season, but when milk yields were low in the dry season, dairy middlemen were much less frequently available or not at all, impacting on household cash flow. Producers also complained about lack of knowledge of market price for milk.

DISCUSSION

The profiles of households described by data collected in this study that owned dairy cattle appear to be in a stronger economic equity position than the non-dairy households based on nearly double to triple the size of land holdings, twice the level of household income and much higher ownership of consumables such as cell phones. The latter is a particularly important indicator of not only wealth but also capacity to access markets including linking with other market agents. It is also important to note that the greater number of dairy households that have access to drinking water and sanitation makes them less likely as a group to be exposed to environmental health risks including coliform bacteria and cholera, frequent hazards that increase in occurrence during flooding. It has not been established that dairy cattle were a reason for the stronger economic equity of dairy households. Unpublished data from researchers

working in the same communities in separate studies indicate differences in economic equity existed prior to selection of livestock. It is more likely that those who were in a better position of economic equity prior to choosing livestock were those households that chose cattle due to the greater demands of base capital needed (for example land, income) over vegetable production for example, and need for frequent access to marketing services for milk sales and dairy inputs. This is yet to be established but has obvious implications for impact of selection factors on change in poverty rates. Key among these implications is the observation that while many households might wish to access cattle, only those that have an economic resource base adequately large enough to support input provision will do so, presumably increasing wealth of households already better off than the majority of non-cattle rearing households.

An appropriate research question might be what changes are necessary for those households not able to raise dairy cattle to allow them sufficient development of the necessary economic resources. This argument has been made for poultry production which can serve as a stepping stone to small scale ruminant production and eventually dairy cattle production. While poultry are kept by many of the vegetable raising households, we did not examine poultry production in this report. Although data gathered show participants report women are only slightly more likely to be the primary caregivers of livestock, personal visit to sites leave the impression that 90% or more of livestock are tended to by women or children. Anecdotal evidence supported by NGO experience in the districts indicates that most men are either no longer involved in the day to day activities of the household because they are engaged in manual labour or other employment activity on the mainland, or because they may have abandoned the family entirely. Poverty was suggested by women we interviewed as the primary reason for abandonment.

Dairy production differences

Due to the obvious environmental differences (that is, breed), it would not be valid to compare significant differences of variables in Table 2 between indigenous and cross-bred cattle, but the results reported by breed do provide some insight into management challenges facing both types of production. Two variables in particular stand out – services per conception and calving interval. Although, the smaller indigenous breed required slightly fewer services per conception than the cross-bred cattle and although both variables in isolation indicate reasonable management, the lengthy calving intervals of both breeds are excessively long. Without any other assessment, these variables alone suggest reproductive health is a major constraint to efficient production. The reason for this is not identified but could be metritis or other reproductive health issues, inadequate nutrition or poor heat detection. This suggestion is strengthened by parallel research conducted by BAU authors of this report in which they assessed the reproductive health of nearly 1500 indigenous cattle and found that 26.4% of cows had recent histories of abortion, dystocia and retained placenta (Alam and Raha, 2011). In that study, basic veterinary reproductive health interventions resulted in 85% of treated cows returning to estrus within three days of treatment and 73% pregnant at 60 to 80 days post service.

Clearly, interventions targeting specific problems can have impact on bovine reproductive health.

Economic differences between dairy producing households

The economic variables reported in Table 3 represent pooled farm data of indigenous cattle used for dairy production in the districts indicated. Lowest feed costs and highest revenues per lactation for dairy cows in Jamalpur led to highest dairy profit and largest ratio of milk revenue to fed costs of the three districts per cow. However, Jamalpur dairy farmers also experienced the lowest manure revenue of the three districts and higher cow purchase prices than Bogra leading to a return on investment (ROI) lower than 1.0. This measure of economic performance indicates producers in Jamalpur failed to recover their investment in one lactation, whereas dairy producers in Bogra and Sirajganj just broke even. The differences are relatively small – ROI for all three districts is close to 1.0 which is not desirable, but considering this is the first lactation and that the value of a calf or current market value of a pregnant cow is not included in the calculation, the ROI could be considered under reported. It is also of interest to note that all farms reported healthy dairy profit for the average lactation, bringing in needed cash revenue from milk and manure sales. Veterinary costs are low although this is underreported due to some provision of veterinary inputs at heavily subsidized value. The impact on potential annual profit from milk sales is not known but the reports of low or lack of market access due to seasonal variation and low bargaining power due to lack of knowledge of price imply that there is a significant loss in potential revenue. Milk revenue is important as it is used to purchase household inputs including clothing, school needs, and food increasing household food security and increasing the likelihood of childhood education.

It is somewhat premature to compare the DDVC successes with the work in the Char regions, but we can at least note that the modified activities in the Char areas have been well accepted by the participants and provide needed regular cash inflow to the households. Participants were keen to integrate livestock, crop, and horticultural agricultural activities and to teach and learn from each

other. Data for analysis of the overall impact on household income and food security is still being gathered and assessed, but preliminary analysis indicates: weekly cash income has increased 60 to 70% for households that invested in cattle; more than 75% households reported increased consumption of vegetables in their diets; and less than 10% of households reported increased consumption of livestock products primarily because it is seen as a source of cash rather than nutrition. This suggests the integrated approach to agricultural activities is contributing to poverty reduction and food security for the Chars residents.

Ecohealth dimensions

It is important to reflect on the aspects of this project and the wider breadth of NGO programmes in the area that constitute an ecosystem approach to health research (or "ecohealth") in the districts. These projects and programmes are addressing at least five of the six pillars of ecohealth (Charron, 2011) and they are briefly identified here: transdisciplinarity in bringing multiple disciplines to the research including veterinary health, horticulture, communications and economics; community participation in the research from the start of the project; addressing gender and economic equity, particularly with regard to economic empowerment of women in the community who are the major caretakers of livestock; knowledge to action in that knowledge from this participatory research is used by the villagers to improve health and well-being through an improved environment (for example, removal of cattle from households); and endeavoring to develop solutions that are sustainable for the community. The sixth pillar not well addressed is that of complexity of systems. This is discussed as follows.

CONCLUSIONS

The success of the Dauki-Damgaon village community integrated agricultural systems projects in northern Bangladesh prompted extension of this effort to the Jamuna River Chars area of the country where the challenges of high rates of poverty and poor food security have been amplified by severe seasonal changes. This paper summarized initial findings of interventions aimed at improving bovine dairy production and health for villagers living in the chars, and reports on some successes with regards to improvements in bovine fertility and increased household income. The analysis also leads to the conclusion that investigation of the broader overarching themes of complexity and systems thinking are needed to identify the various elements and linkages of village level activities, community participation, and market opportunity development that lead to sustainable improved health and livelihood outcomes. The authors intend to address this in future work which will include incorporation of a comprehensive package of veterinary health services and market development delivered as two themes of a comprehensive programme that will also attend to other village level needs including primary education, maternal health care and environmental stewardship. While there are much larger programmes in the Jamuna River Chars region including the previously mentioned and successful Chars Livelihoods Programme, none that we are aware have taken an integrated approach with evaluation of complexity and systems thinking in order to inform strategies for future development.

These observations for future work are encouraging, although research in the growing field of complexity and systems analysis suggests this will be a considerable - though necessary - challenge to understanding and planning for sustainable growth in the Chars areas of northern Bangladesh.

RECOMMENDATIONS

The results reported here are in many ways summary observations of demographic, production and economic variables measured at various times during this first stage of the entire project. The results of this first stage are valuable to inform the direction in which the project proceeds which includes input from the participants. The main observation from village participants is that they desire further technical training in matters such as dairy feeding and milk preservation. A second observation is needed for regular and consistent delivery of health services including veterinary and marketing services and development. With regards to markets, despite the higher incidence of cell phone ownership and access to middlemen, dairy producing villages complained of a lack of awareness of current milk price and transaction costs, suggesting a strong and deliberate information asymmetry aimed to increase profit margins of other elements of the milk marketing chain. Finally, participants have requested better understanding of the relation between health of animals, humans and their environment. This third request stems from recommendations made by researchers for villagers to remove their cattle and goats from their homes at night where they are usually kept for security reasons.

The villagers were interested to learn of the health risks to humans from keeping livestock inside their homes due to coliforms and listeria for example, and were curious to know about relationships between other elements of their environment including water sources, crop cycles and how to manage village decisions about competitive markets in light of these relationships.

Complexity and systems thinking

The various animal health and production elements of this study aimed to address health and nutrition outcomes, particularly with respect to food security and poverty reduction. This may have been achieved in a small way by increasing household income through improved dairy

production. However, the desire of villagers for understanding better the relationship between animals, humans, and their environment (that is, knowledge of ecohealth) as well as the somewhat disjointed and compartmentalized elements of the research project reported in this paper suggest that two major cross-cutting themes were not well captured by the research approach used in this project. Despite embracing an integrated agricultural approach at the village level, the research approach did not do a good job of identifying and analyzing complexity and systems thinking, two cross-cutting concepts we suggest are essential to bringing together the various component elements of a research methodology that addresses a multi-factorial problem such as the impact of livestock health and production on the economic development of a village where resources are severely constrained. While the study design of various elements of this project could have been improved considerably by clearer and more comprehensive data collection objectives implemented more frequently, examining various components of this project in exclusion of their contribut-ion to larger objectives, as has been done in this paper (for example, impact of improved dairy reproductive health in absence of how that has changed access to markets and the steps in that process), neglects the broader issues of complexity and systems thinking.

Considering that a system is a set of interconnected elements functioning as a unit, as should be the case of a successful village economy, complexity examines the relationships between those interconnected elements. Complexity examines a system in part and in whole and asks such questions as what is the mechanism of influence and impact on outcomes, why does a change in focus occur, and how might such changes result in requirements to shift tactics and redesign strategies. All of these points are pertinent to the agricultural based systems of Bogra, Jamalpur, and Sirjgonj in rural Bangladesh which are dependent and responsive to the occasionally extreme seasonal environmental changes they experience annually. The many aspects of change in natural systems and impact on the complexity of human relationships have been explored by several authors (Gunderson and Holling, 2001; Berkes et al., 2002). While the detail of those concepts is left to the reader, we can conclude that where small-scale societies face large-scale disturbances such as extensive flooding, the presence of multiple species managed within an integrated system increases the likelihood of long-term ecosystem sustainability and resilience of that ecosystem. The contribution of dairy cattle to the Chars ecosystem surely provides more than economic benefits to the households; it also provides one more species among the rice, vegetables, and fish which increases the opportunity for cycling of natural resources that in some way contribute to food security.

The intricacies of this and the economic impact to the community are yet to be explored.

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