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Human wetland dependency and socio-economic evaluation of wetland functions through participatory approach in rural India

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Abstract: Wetlands are an important source of natural resources upon which rural economies depend. They have increasingly been valuable for their goods and services, and the intrinsic ecological value they provide to local populations, as well as people living outside the periphery of the wetlands. Stakeholders' participation is essential to the protection and preservation of wetlands because it plays a very important role economically as well as ecologically in the wetland system. The objective of this study was to determine whether gender, educational status, mouzas (which are constituents of a block according to the land reform of the West Bengal Government in India), and wetland functions have any influence on the annual income of the local community. Considering a floodplain wetland in rural India, the focus was extended to recognize the pattern of wetland functions according to the nature of people's involvement through cluster analysis of the male and female populations. Using the statistical software R-2.8.1, an ANOVA (analysis of variance) table was constructed. Since the p value (significance level) was lower than 0.05 for each case, it can be concluded that gender, educational status, mouzas, and wetland functions have a significant influence on annual income. However, S-PLUS-2000 was applied to obtain a complete scenario of the pattern of wetland functions, in terms of involvement of males and females, through cluster analysis. The main conclusion is that gender, educational status, mouzas, and wetland functions have significant impacts on annual income, while the pattern of occupation of the local community based on wetland functions is completely different for the male and female populations.

Key words: *wetland dependency; socio-economic evaluation; wetland functions; rural India; cluster analysis*

1 Introduction

Wetlands are generally highly productive ecosystems, providing various important benefits to the environment. These benefits are mainly flood control, groundwater recharge, and pollution reduction (Bhattacharya et al. 2008) as wetlands act as aquatic filtering systems (Boyer and Polasky 2004). Wetland ecosystems are multilateral ecosystems that provide

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substantial benefits to society through their numerous functions and services. However, their important role in maintaining the economy of their regions is not properly perceived, and almost all wetlands in India are endangered due to lack of appreciation of their role. A few of the country's wetlands, which have a great deal of biological wealth, are protected under the Wildlife Protection Act (MOEF 1972). Some are included within the purview of the Ramsar Convention (an intergovernmental treaty aiming to conserve wetlands as a habitat for water birds), including Chilka, Wular, and East Calcutta wetlands, but there are many wetlands that are not adequately assessed or protected and thereby become easy targets for developers (Biswas et al. 2005). Estimates of monetary value of wetlands and attitudes towards wetland conservation are the major factors to be considered in policy decisions. Both use and non-use values are associated with wetlands (Scodari 1990), with use values including those resulting from direct use, such as production of fish and other aquatic flora and fauna. Sustainable livelihood development of wetland communities requires multidisciplinary and integrated efforts in addressing constraints in the various sectors, such as agriculture, natural vegetation use, water resources, and fishing (Kangalawe and Liwenga 2005).

In view of these various wetland services and functions, many researchers have identified the originality of the wetland inventory and its management for the society in particular. Haq et al. (2005) focused on soil-less agriculture as an alternative source of livelihood in the central southwestern part of Bangladesh where the productivity of the wetland ecosystem based on special kind of farming is much higher than that of terrestrial agricultural and supportive to open water fisheries, an eco-friendly technology. Adhikari et al. (2004) and Anderson et al. (1998) analyzed the relationship between key household characteristics and common property resources of a community-based forest in Nepal, providing an idea for assessment and development of the relationship between wetland attributes. Alam and Begum (2005) considered a community-based fisheries management project to organize and cultivate fisheries in Ashurar Beel in Bangladesh. Kangalawe and Liwenga (2005) focused on the opportunities and challenges related to integrated water resources management in Kilombero Valley, Tanzania, and on the dynamics and benefits of natural resource use in wetlands. Mbaiwa (2003), furthermore, explained the dependency paradigm and the development of enclave tourism and its socio-economic impacts in the Okavango Delta, Botswana. Nyakaana (2008) evaluated the socio-economic benefits of consumptive utilization of wetland resources, the recreation and eco-tourism potential of wetlands, and their sustainability and contribution to poverty reduction in the surrounding communities. However, Kataata (1996) emphasized that wetland conservation depends on weather patterns suitable for agricultural production. Söderqvist et al. (2000) suggested that an integrated wetland research framework that combines economic valuation, integrated modeling, stakeholder analysis, and multi-criteria evolution can provide complementary insights into sustainable and welfare-optimizing wetland management and policy. Based on a study of mangroves in Vietnam, Adger and Luttrell (2000) argued that the rationale for conversion is the quick income-generating capability of aquaculture (mostly shrimp) and agriculture, considering that short-term return benefits decrease after a few harvests. Singh et al. (2002) evaluated costs and benefits of resources and the water quality degradation in Lake Nainital. The stock of wetlands, thus, is a multifunctional resource, having a highly significant economic value, upon which the people around the wetlands depend through their occupations. Naturally, the total occupational structure of the stakeholders depends on the different wetland functions, which means that the occupations of the people around the wetland are based on the various wetland functions. These studies were mainly concentrated on wetland functions (such as farming, fishing, and agriculture) and wetland attributes (such as education and socio-economic value). However, there is no such research related to all the major wetland functions or socio-economic evaluation linked with the wetland economy in the Indian context.

Beyond its potential usefulness as described by various researchers, there is a more fundamental reason for a study of society's impact on the economy of the wetland, which is an issue usually neglected within the scientific community due to its complexity. The present study deals with how human status is related with the wetland economy, considering its numerous functions and attributes, and may be of great value for the scientific community, providing a framework for clustering the occupations of stakeholders through a participatory approach, particularly in rural India. In view of wetland conservation, this study emphasizes the use of economic valuation as an incentive. The environment's available services are valuable but these values are seldom recognized and quantified and also are often lost through inappropriate development or used inefficiently without the help of eco-friendly technology. Linkages between the use values available and some selected wetland functions (farming, fishing, and agriculture) are stressed in the study. The study emphasizes that appropriate incentives can only be developed in an integrated participatory approach once the values derived from these wetland functions and/or occupations are recognized. The wetland functions, attributes, and services or products are the major aspects to be considered in the integrated management of the wetland ecosystem and its valuation, which are achieved by establishing the linkages between the wetland variables and the community. The available data on various attributes and functions were examined in the present investigation for the socio-economic valuation of the wetlands considering community dependence on them. The role of the public participation approach in initiating wetland valuation studies is emphasized. Evaluation is also attempted of a complete scenario of patterns of wetland functions according to the nature of involvement of people and the significant effects of gender, educational status, mouzas, and wetland functions on annual income, through cluster analysis for male and female populations living in and around the study floodplain wetland.

2 Materials and methods

2.1 Study area

In the present investigation, Bhomra Beel (22°59'N-23°00'N and 88°38'E-88°40'E), a floodplain wetland located in rural eastern India was considered in view of the pressure of the surrounding population in terms of farming, fishing, and agriculture. This wetland is under the administration of Kastadanga-1 and Kastadanga-2 Gram Panchayet (a local administrative body formed by elected members from different villages) in the Haringhata Block of Nadia District, West Bengal. It is an oxbow lake, which derives its origin from the Yamuna River, as shown in the land use map (Fig. 1) and is owned by the Government of West Bengal and managed by the Bhomra Fishermen's Cooperative Society. More than 90% of farmers in the village practice subsistence agriculture and their livelihoods depend upon wetland-based agro-biodiversity resources. This is a non-perennial wetland, which nearly dries up during the months of April, May, and June. The total area covered by the wetland is 2.64 km^2, and the water depth of this wetland varies from 2.5 m (during September and October) to 1.5 m. It is the cutoff portion of river meanders. The basin is relatively narrow, long, and deep, and has either bent or straight shapes. It derives its name from its horseshoe, crescent, or serpentine shape. It receives water from the Yamuna River through the old channel or neighboring catchments following monsoon rains or during high floods.

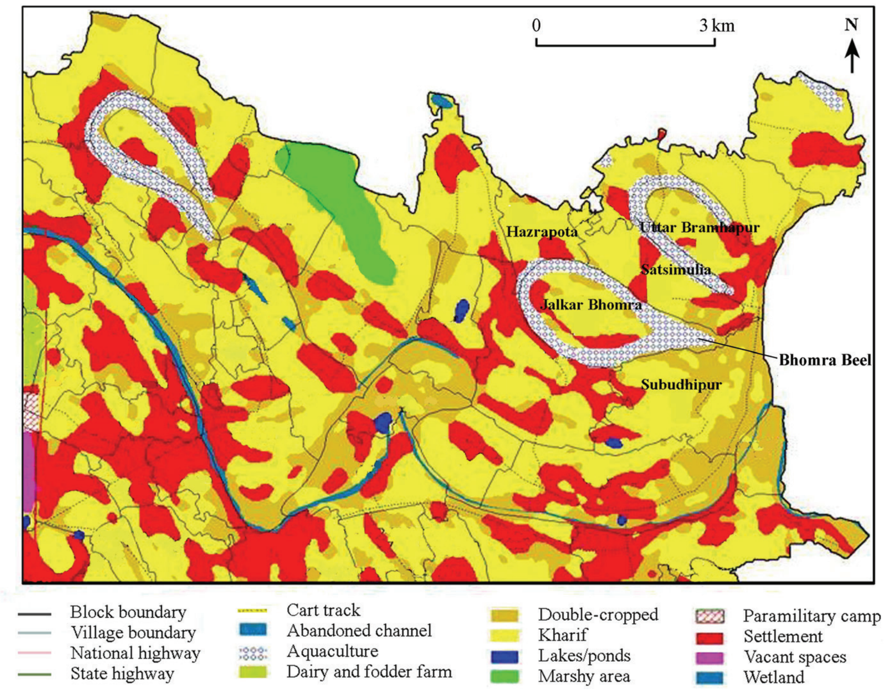

Fig. 1 Land use map of Bhomra Beel

The main wetland plants are algae, water hyacinth, and water lily. The water is used for pisciculture, domestic and agricultural purposes. Fishing is practiced on a commercial basis using modern fishing implements. In the past, this water body used to get polluted due to the rotting of raw jute, but now this problem has been done away with and mat sticks are prepared from one of the wetland plants. Tortoise, ducks, and frogs are also found in this wetland. In recent years, riverine embankments have been constructed to prevent floods and have converted many open wetlands into closed ones by blocking the riverine connections.

2.2 Data acquisition

The present study is mainly based on primary data and information collected through a household survey in five mouzas, Jalkar Bhomra, Hazrapota, Subudhipur, Uttar Bramhapur, and Satsimulia, in and around the wetland system during the period from 2002 to 2007. A stratified sample of households was chosen by compiling a census of village households with participatory rural appraisal techniques (Adhikari et al. 2004). The proportional sample sizes of male and female populations are shown through bar charts for each mouza in Fig. 2. This study considered the data through formal surveys and interviews, which were analyzed by using descriptive statistics to address the management and possible utilization practices of wetland resources management.

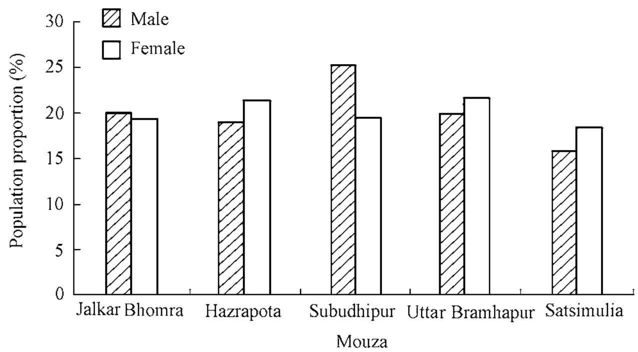

Fig. 2 Proportional sample sizes of male and female populations

2.3 Statistical analysis

This study attempted to construct a linear model and to analyze the wetland inventory through cluster analysis using the available software packages Minitab-15, R-2.8.1, and S-PLUS 2000 with the operating system Windows XP, Service Pack 2. The software, Minitab-15, gives a clear diagrammatic representation of the data, while R-2.8.1 and S-PLUS 2000 offer relatively quick, detailed, and flexible estimates of unknown coefficients of the model, analysis of variance with corresponding testing of a hypothesis, and cluster analysis.

2.3.1 Model development and hypothesis testing

The multiple linear regression model was developed as follows:

A statistical model was formulated to reflect the influence of gender, educational status, mouzas, and wetland functions on annual income. Here we consider the following linear equation, which shows the annual income as a function of wetland functions and other variables:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + e \tag{1}$$

where y is a dependent variable, which is the annual income of individuals in the study area; the independent variables x_1, x_2, x_3, and x_4 represent gender, educational status, mouzas, and wetland functions, respectively; β_0 is the general effect coefficient (or so-called regression constant), and β_1, β_2, β_3, and β_4 are the regression coefficients in the linear regression analysis; and e is an unobserved random error including the factors other than the regression coefficients with which the dependent variable y is correlated. Here, the coefficients β_0, β_1, β_2, β_3, and β_4 are unknown and need to be estimated.

In this model, we assume that the error is random in nature reflecting other factors that influence the annual income and e is assumed to follow the normal distribution N (0, σ^2), where σ^2 is the variance. There is no presence of heteroscedasticity and multicollinearity because the error has homogeneous variance with zero correlation. Our purpose was also to examine whether there are any significant effects of the explanatory variables (gender, educational status, mouzas, and wetland functions) on the income factor or not. Thus, a procedure was performed to test the null hypothesis, $\beta_1 = \beta_2 = \beta_3 = \beta_4$, against the alternative hypothesis, which is that the null hypothesis is not true in at least one case.

2.3.2 Cluster analysis

Cluster analysis is a data reduction method that is used to classify entities with similar properties within a data set based on some quantitative measurements of similarity. The method divides a large number of objects into a smaller number of homogeneous groups on the basis of their correlation structure (Hartigan 1975). The purpose of cluster analysis is to find the groups whose objective function has similar properties. The inputs to the cluster analysis are similarities or dissimilarities (Das and Chattopadhyay 2004). Level of similarity or degree of similarity is based on any given metric, in this case the Euclidian distance between two observations. Here we defined the cluster level measured on a Euclidian distance scale where the minimum value implies a high degree of similarity and the maximum value implies a low degree of similarity.

3 Results and discussion

3.1 Proportional sample sizes of male and female populations in each mouza

Population sampling and the sampling size for all mouzas is a prime requirement for investigation of the socio-economic conditions derived from the wetland. We collected the maximum number of male samples from Subudhipur and the maximum number of female samples from Uttar Bramhapur. From Satsimulia, we collected the minimum number of samples for both genders. In this case, it is very important to mention that from each mouza we first selected 50 families, and from these 250 families of five mouzas, a total sample size of 1437 males and females was considered.

3.2 Role of educational structure of male and female populations in wetland economy

The educational structure of the male and female populations, as shown in Fig. 3 for all mouzas, has an indirect dependence on the wetland system in terms of revenue generation. It is observed that for all five mouzas the numbers of illiterate males are almost the same.

Moreover, most of the male population in Uttar Bramhapur and Subudhipur have finished their education up to class 4 (i.e., four years of education), while, except for Satsimulia and Uttar Bramhapur, there is almost the same number of males with an educational level between class 5 and class 10 in all mouzas. However, highly educated (with more than 12 years of education) males are few in all mouzas. It is observed that most females in the sample domain have a moderate level of education, because the data are concentrated mostly in two groups, the group lower than or equal to class 4 and the group between class 5 and class 10. Moreover, the number of illiterate females is large in all mouzas while the number of highly educated females is small in all mouzas.

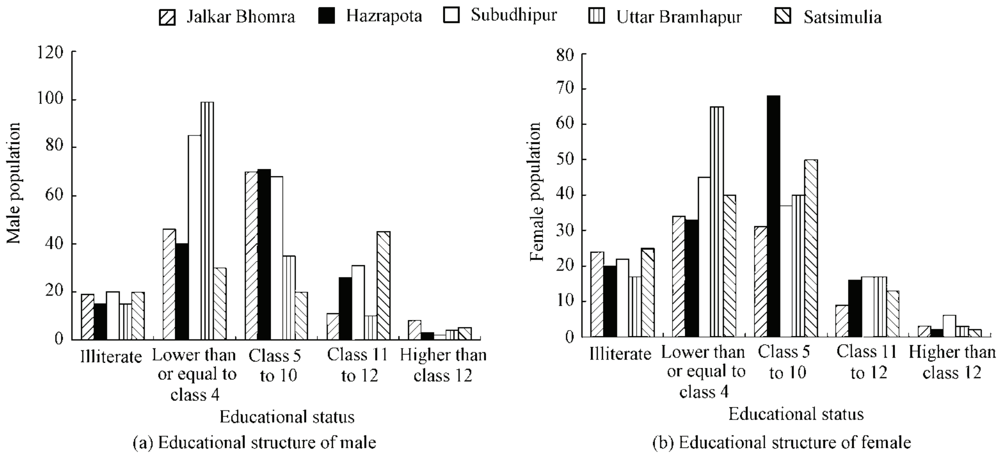

Fig. 3 Educational structure of male and female populations in and around study area

It can be concluded that the educational status and/or level of the male and female populations in the study area is quite dependent on the wetland ecosystem in terms of the income generation and livelihood. Detailed descriptive statistics of the educational structure of the male and female populations in all mouzas are given in Table 1 in order to describe the characteristics of the data more clearly.

Table 1 Descriptive statistics of educational structure of male and female populations

Gender	Educational status	Mean	Standard deviation	Variance	Minimum	Median	Maximum
Male	Higher than class 12	4.40	2.30	5.30	2	4	8
	Class 11 to 12	24.60	14.64	214.30	10	26	45
	Class 5 to 10	52.80	23.72	562.70	20	68	71
	Lower than or equal to class 4	60.00	30.17	910.50	30	46	99
	Illiterate	17.80	2.59	6.70	15	19	20
Female	Higher than class 12	3.20	1.64	2.70	2	3	6
	Class 11 to 12	14.40	3.44	11.80	9	16	17
	Class 5 to 10	45.20	14.48	209.70	31	40	68
	Lower than or equal to class 4	43.40	13.01	169.30	33	40	65
	Illiterate	21.60	3.21	10.30	17	22	25

It is observed from Table 1 (and also from Fig. 3) that most of the population (74%) in these mouzas have a low level of education, so their livelihood strongly depends on the wetland system and its various attributes. Moreover, the scenario of wetland functions and their dependence are not the same for both genders. The data for male and female populations need to be analyzed separately.

3.3 Occupation-based wetland functions and attributes

The structure of the occupation-based wetland functions for male and female populations is detailed in Fig. 4. The majority of the male population depends on agriculture, i.e., most of the male population are farmers and landless laborers according to the socio-economic survey. In the sample of the male population, there are no people in Subudhipur and Hazrapota mouzas whose occupation is animal husbandry. In Satsimulia there are no people engaged in cottage industry. The dependency of the male and the female populations on various wetland functions is completely different, as observed from the statistics of the data, where the female population mainly depends on animal husbandry. Moreover, there are no farmers or fishermen in the sample of the female population in all the five mouzas as reflected in Fig. 4(b).

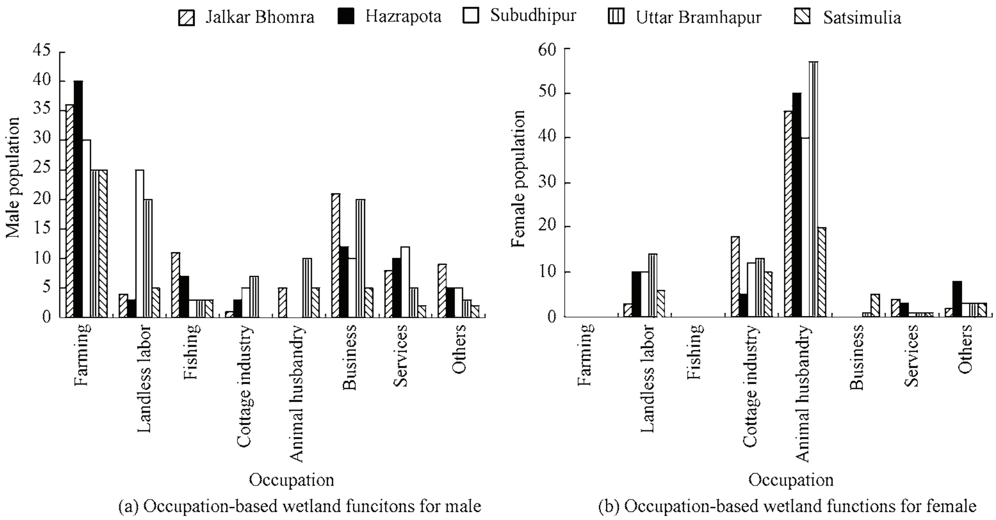

Fig. 4 Occupation-based wetland functions for male and female populations

The descriptive statsitics of wetland functions for the male population were considered in order to identify the dominant variable that is directly or indirectly linked to gender and its dependence. The range of different wetland functions given in Table 2, with their descriptive statistics, was calculated in order to visualize the data more distinctly for male and female populations. It may be concluded that the percentage of the male and female populations that depend upon a particular wetland function is again locally or regionally dependent. It may also be a choice/attitude or tendency toward a particular wetland function where the wetland services and the wetland economy are at the peak level.

Table 2 Descriptive statistics of occupation-based wetland functions for male and female populations

Gender	Occupation	Mean	Standard deviation	Variance	Minimum	Median	Maximum
Male	Farming	31.20	6.69	44.70	25	30	40
	Landless labor	11.40	10.31	106.30	3	5	25
	Fishing	5.40	3.58	12.80	3	3	11
	Cottage industry	3.20	2.86	8.20	0	3	7
	Animal husbandry	4.00	4.18	17.50	0	5	10
	Business	13.60	6.80	46.30	5	12	21
	Services	7.40	3.97	15.80	2	8	12
	Others	4.80	2.68	7.20	2	5	9
Female	Farming	0	0	0	0	0	0
	Landless labor	8.60	4.22	17.80	3	10	14
	Fishing	0	0	0	0	0	0
	Cottage industry	11.60	4.72	22.30	5	12	18
	Animal husbandry	42.60	14.06	197.80	20	46	57
	Business	1.20	2.17	4.70	0	0	5
	Services	2.00	1.41	2.00	1	1	4
	Others	3.80	2.39	5.70	2	3	8

3.4 Verification of model results

The influence of gender, educational status, mouzas, and wetland functions on annual income was verified by the linear statistical model. The socio-economic status of the people who live in and around the wetland is well reflected, considering the multiple wetland functions and attributes. In order to obtain a complete view of the dependency of the socio-economic status of local people on wetland functions and other factors, including gender and educational status, with the spatial importance of the wetland, it is essential to determine whether there is any influence of gender, educational status, mouzas, and wetland functions on annual income.

The unknown coefficients in Eq. (1) are determined using the method of least squares incorporated with the statistical model: β_0 is 6 196.718, β_1 for gender is –346.838, β_2 for educational status is 3 490.611, β_3 for mouzas is 1 031.272, and β_4 for wetland functions is –1 308.673. In this case, the gender and the wetland functions have negative effects on the model, while the general effects, educational status, and the mouzas have positive effects on the model. Thus, the wetland economy is invariably related to the negative and positive effects of the unknown coefficients proposed in the model.

The data were subjected to ANOVA (analysis of variance) using the statistical software R-2.8.1 to test the difference in significance among the treatments, as shown in Table 3. In this table, the degree of freedom, sum of square, and mean of square for each variable are presented along with significance levels (p values). The sum of square is the sum of the squared deviations (deviation is the difference between the data and the mean data). The mean of square is equal to the sum of square divided by the degree of freedom. The residual in the table indicates the difference between the fitted value in the model equation and the actual value for each observation. The residual group in the ANOVA encapsulates all the other factors that have not been identified with the above groups, namely, gender, educational status, mouzas, or wetland functions. The degree of freedom for the residual is very large, because it incorporates a number of independent data that is excluded from the above data classifications (degree of freedom for the residual is equal to the number of observations minus 1). The p value obtained from one-way ANOVA should be very small (lower than 0.05) to successfully infer that the null hypothesis is rejected. This is the case when the level of significance considered is 0.05. f is the ratio between explained variability and unexplained variability, mathematically calculated as the ratio of the mean of square between groups to the mean of square within groups. Based on ANOVA, it is concluded that gender, educational status, mouzas, and the occupation-based wetland functions have significant effects on the dependent variable, i.e., income.

Table 3 ANOVA table

Variable	Degree of freedom	Sum of square (10^9)	Mean of square (10^9)	f value	p value
Gender	1	2.508	2.508 0	7.958 593 1	< 0. 000 1
Educational status	1	5.271 8	5.271 8	16.729 003	< 0. 000 1
Mouza	1	1.075 1	1.075 1	3.411 610 5	< 0. 000 1
Wetland function	1	6.532 3	6.532 3	20.728 995	< 0.004
Residual	1 231	0.642 55	0.000 521 97	0.001 465 8	< 0.000 1

People depend on wetlands for water, medicine, food, building materials, and functions for different occupations (Schuyt 2005). The villagers around this wetland have little education and their lifestyle as well as their occupation depends on the stock of the wetland in direct and indirect ways. It is also observed that there are some wetland functions in which the male population is involved more than female population, and there are some wetland functions on which the female population is more dependent than the male population. A complete scenario of wetland functions, that is, the different homogeneous classes of wetland functions in terms of community involvement, was examined. Cluster analysis can be used to link variables (wetland functions) in the configuration of a tree with different branches (involvement of the male population and female population, separately) that have stronger linkages to each other, indicating stronger relationships among variables or clusters of variables. Different clusters of wetland functions according to the number of people involved through the cluster analysis were created for better understanding of these wetland functions and attributes as shown in Table 4, for the male and female populations.

C is the cluster set, and $C = \left(C_1, C_2, \ldots, C_7\right)$. E denotes the wetland functions, and

$E = (E_1, E_2, \ldots, E_8)$, where E_1 indicates farming, E_2 indicates landless labor, E_3 indicates fishing, E_4 indicates cottage industry, E_5 indicates animal husbandry, E_6 indicates business, E_7 indicates services, and E_8 indicates others. The third column describes the constituents of a particular cluster. They could be a combination of two clusters, or two wetland functions, or a cluster and a wetland function. For example, the entry [E_3 E_8] means that the wetland functions E_3 and E_8 are similar (cluster level is 3.605 551) and fall in cluster C_1. The entry [C_1 E_7] means that the wetland function E_7 is similar to cluster C_1 (cluster level is 9.543 117). The entry [C_3 C_2] shows that the clusters C_3 and C_2 are similar to each other. In the fourth column we can observe the cluster level between the two wetland functions, or between two clusters, or between clusters and wetland functions. It is observed that for the male population, the wetland functions, fishing, and other occupations have a cluster level at 3.605 551, where the cluster level between farming and other wetland functions is 56.736 865. There are no fishermen or farmers in the female population and these two wetland functions are at the lowest level, i.e., 0. Animal husbandry is at a cluster level of 91.039 875 with other wetland functions as represented in Table 4. Thus the major occupation in the male population is farming and in the female population is animal husbandry, on which the economy is largely dependent apart from the other wetland-based occupations.

Table 4 Cluster analysis of wetland functions for male and female populations

Gender	C	Constituents of C	Cluster level
Male	C_1	[E_3 E_8]	3.605 551
	C_2	[E_4 E_5]	9.165 151
	C_3	[C_1 E_7]	9.543 117
	C_4	[C_3 C_2]	12.345 547
	C_5	[C_4 E_6]	23.110 272
	C_6	[E_2 C_5]	25.612 174
	C_7	[E_1 C_6]	56.736 865
Female	C_1	[E_1 E_3]	0
	C_2	[C_1 E_6]	5.099 020
	C_3	[C_2 E_7]	5.687 915
	C_4	[C_3 E_8]	8.779 064
	C_5	[E_2 E_4]	16.462 078
	C_6	[C_4 C_5]	21.961 363
	C_7	[C_6 E_5]	91.039 875

4 Conclusions

Wetlands are among the most important and yet most threatened ecosystems in India. Bhomra Beel, an Indian wetland, is non-perennial in its floodplain area. Fishing is its major function throughout the year, as opposed to agro-irrigation, for which huge water withdrawal is necessary. The main conclusions of this study are as follows:

(1) The dependency and economic productivity of the studied wetland are found to be correlated with occupation, gender, and spatial variation of the local population (in mouzas), as observed through quantitative and qualitative analysis. There is a distinguishable pattern in the educational structure of the male and female populations, where the male population is dependent particularly on fishing and farming, and the female communities are engaged mainly in animal husbandry and cottage industry.

(2) The livelihood of the community living in and around the wetland benefits from a lot of services. For example, farmers and landless laborers use the water bodies for irrigation purposes. Fishermen, cottage industrialists, and people engaged in animal husbandry and other occupations use water bodies indirectly, whereas service providers and businessmen use the water bodies in either direct ways or indirect ways.

(3) The development of this multiple linear regression model is the baseline for reflecting the importance of the wetland in stakeholders' livelihoods through various wetland functions, and providing a relationship between gender, educational status, mouzas, and wetland functions, and annual income of the stakeholders. Moreover, the significant effects of gender, educational status, mouzas, and wetland functions on income as well as the extent of dependence are observed. Gender and the occupation-based wetland functions have a negative effect on income while the other factors have positive effects on income. The economy of the participatory community is directly linked to the wetland economy and indirectly influenced by the various wetland functions and attributes.

(4) It can be seen that the female population does not benefit from fishing and farming, as the clustering of fishing and farming is at the lowest level shown in Table 4, while the clustering of animal husbandry with other wetland functions is at the highest level, which implies that the major occupation for females is animal husbandry.

(5) It can be concluded that the involvement of males in different wetland functions and attributes differs from that of females. The cluster analysis further shows that the dependence of stakeholders' livelihoods on the wetland is subject to their gender. Thus, in order to obtain a technologically feasible solutions to the various serious problems and challenges in wetland management resulting from top-down approaches to resource conservation, restoration, and sustainability, community-based co-management recognizes that local communities should have direct control over the management, utilization, and benefits of local resources, such as land, water, and fishery resources, to valuate and use them in a sustainable manner.

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