Determinants of Pitlake Usage in Raniganj Coalfield Region, West Bengal: Implications for Sustainable Use

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ABSTRACT
Aquatic environment like lakes are bestow with good and life supporting environment. Surface mining generated pit lakes though limits this proposition but there are exceptions. Utilization of Pit lakes in Raniganj Coal field region, West Bengal have been investigated during 2014-2016. Around 7 uses/Pitlakes on an average were observed with a maximum of 11uses/pit lake(s) in the studied region. Older pit lakes having better ecological health than younger one are characterized by greater number of uses. Similarly it was established that Recreational fishing (CCA score = 0.8906), Food source use (0.8874) and Domestic use (0.8721) are the highly performed practices in these pit lakes based on the ecological attributes and human preference study. Notable observation from the study include relatively old pitlakes are used as collection sites for food source (0.9251) followed by recreational fishing (0.9212) and domestic use (0.9078) by the inhabitants in surrounding villages/locality.

Keywords
Water, Pitlake use, Coal mines, CCA, Ramsar, Sustainable use.

1. INTRODUCTION
Fresh water resources of the world are repository of rich biodiversity [1-4]. They control the ecological processes in the concerned areas [5]. They provide a number of benefits free of cost to human society [6]. Studies on freshwater resources in connection with their ecology, biodiversity, multipurpose usages and conservation are investigated by researchers [7-9] in different parts of the world. Though empirical studies are more concerned with freshwater resources with natural origin however manmade freshwater ecosystem also receives importance during past few decades than their natural counter parts [10-13]. In Indian subcontinent, several authors contributed towards in depth assessment of freshwater resources which include the works pioneered by [14-16]. Ecological assessment of freshwaters in this region was investigated by [17-19]. Studies on freshwater biodiversity in India was carried out by [20-23].

Coal mine pit lakes are generated as a consequence of open cast mining process. Large excavated areas bearing vertical walls and enormous quantity of water typically characterize these aquatic systems. Mining companies have limited liabilities regarding the safe usages of their water resources. Subsequently the pitlake adjoining areas receive less attention and improper managerial decisions.

In West Bengal, especially in RCF (Raniganj Coal Field) region, open cast mining has become increasingly common over the last few decades through changes in excavation technology and ore economics. Moreover, such operations frequently leave a legacy of open mine pits once mining ceases. But few or limited number of attempts are exists regarding the surface mining generated pit lakes in this region [24].

Pitlakes originated through opencast coal mining processes are relatively unexplored in this ecoregion. Keeping parity with this proposition, the authors took the responsibility to study the utilization scenario of pitlakes in Raniganj Coal field region for the first time towards better management of these aquatic landscapes. Specifically the objectives of the present study includes: a) documentation and assessment of the major uses of

Pitlakes in RCF region and b) to investigate the factors which determines the uses by stakeholders.

2. MATERIAL AND METHODS

2.1 Study site

Raniganj Coalfield is the birth place of coal mining in the country. Area of Raniganj Coalfield (Figure 1) is 1530 Km-2 spreading over Burdwan, Birbhum, Bankura and Purulia Districts in West Bengal and Dhanbad District in Jharkhand. Heart of Raniganj Coal Field (RCF) is, however, in Burdwan District bounded by Ajoy River in North and Damodar River in South. The preliminary survey on pitlakes of RCF area was conducted during the period of 2014 to 2016. Random sampling of study area was carried out. In this survey, a total 38 pitlakes in Raniganj Coal field area of West Bengal were investigated for assessment of their utilarian scenario.

2.2 Survey of pit lakes for 'utilization pattern recognition' (UPAR1)

Under UPAR1; Villages around the pit lakes are systematically surveyed during the study period to document the existing utilization pattern. Different user groups in the vicinity of RCF pitlakes were interviewed during the periodic visit. A survey questionnaire (modified from 25, 26) was used as a survey during field investigation, key informant interviews and group interviews (consisting of 3-12 persons/group) towards assessing the utilization profile of pitlakes. Direct observations during the field study was conducted and pit lake uses were photographed in the spot.

2.3 Statistical analyses

Statistical analyses were performed using the statistical package XLSTAT [27]. Multivariate statistics were used to get a glimpse on the present utilization of RCF-WB Pit Lakes by using Canonical Correspondence Analysis [28] or CCA covering Pit lakes characterization and use pattern attributes to derive the concurrent trend of resource utilization in different pit lakes. QGIS 2.6.1; DIVA-GIS (7.5.0.0) and *Bhuvan* were used for land use mapping of inventoried pitlakes [29,30,31].

3. RESULTS

UPAR1 demonstrates the concomitant utilization profile of RCF pit lakes measured during the study period (Table 1). In most of the pit lakes multiple uses were observed. All of the uses were proportionately related with the age of the pit lakes. Pit lakes aged over 20-30 years turned naturally into wetland ecosystem harboring a good amount of aquatic biota, excellent water quality and stabilized embankment. All of these attributes in recent decades produces some good number of pitlakes having multifarious prospect. Our study revealed a total of 13 major uses of pitlakes in RCF, WB region. Around 7 uses/pitlakes were observed with a maximum of 11uses/pitlakes and a minimum of 1use/pitlake (Figure 2).

Recreational fishing by villagers was the most frequent use which was observed in 34 pitlakes (89.47%) followed by Pisciculture (Commercial fishing) in 18 pitlakes (47.37%).Thirty three pitlakes (86.84%) were used mainly for domestic purpose. Livestock bathing (12 pitlakes, 31.58%), Religious use (15 pitlakes, 39.47%) and Aesthetic use (27 pitlakes, 71.05%) were some of the rigorously performed practices in these study sites. In Nine pitlakes (23.68%) we observed excellent and efficient irrigation chiefly for water supply and agriculture in the vicinity.

Table 1. Utilization profile of pitlakes measured during the study period.

Use Category	No. of observations	Subcategory	Number of Pit Lakes	Rel. frequency per category (%)
Piscicultural Use	38	Absent	20	52.63
		Present	18	47.37
Recreational Fishing Use	38	Absent	4	10.53
		Present	34	89.47
Irrigational Use	38	Absent	29	76.32
		Present	9	23.68
Domestic Use	38	Absent	5	13.16
		Present	33	86.84
Livestock Bathing Use	38	Absent	26	71.05
		Present	12	31.58
Religious Use	38	Absent	23	60.53
		Present	15	39.47
Drinking Water Use	38	Absent	29	76.32
		Present	9	23.68
Aesthetic Use	38	Absent	11	28.95
		Present	27	71.05
Vehicle Washing Use	38	Absent	29	76.32
		Present	9	23.68
Food Source Use	38	Absent	3	7.89
		Present	35	92.11
Thatching Material Use	38	Absent	25	65.79
		Present	13	34.21
Fodder Use	38	Absent	19	50.00
		Present	19	50.00
Water Supply Use	38	Absent	27	71.05
		Present	11	28.95

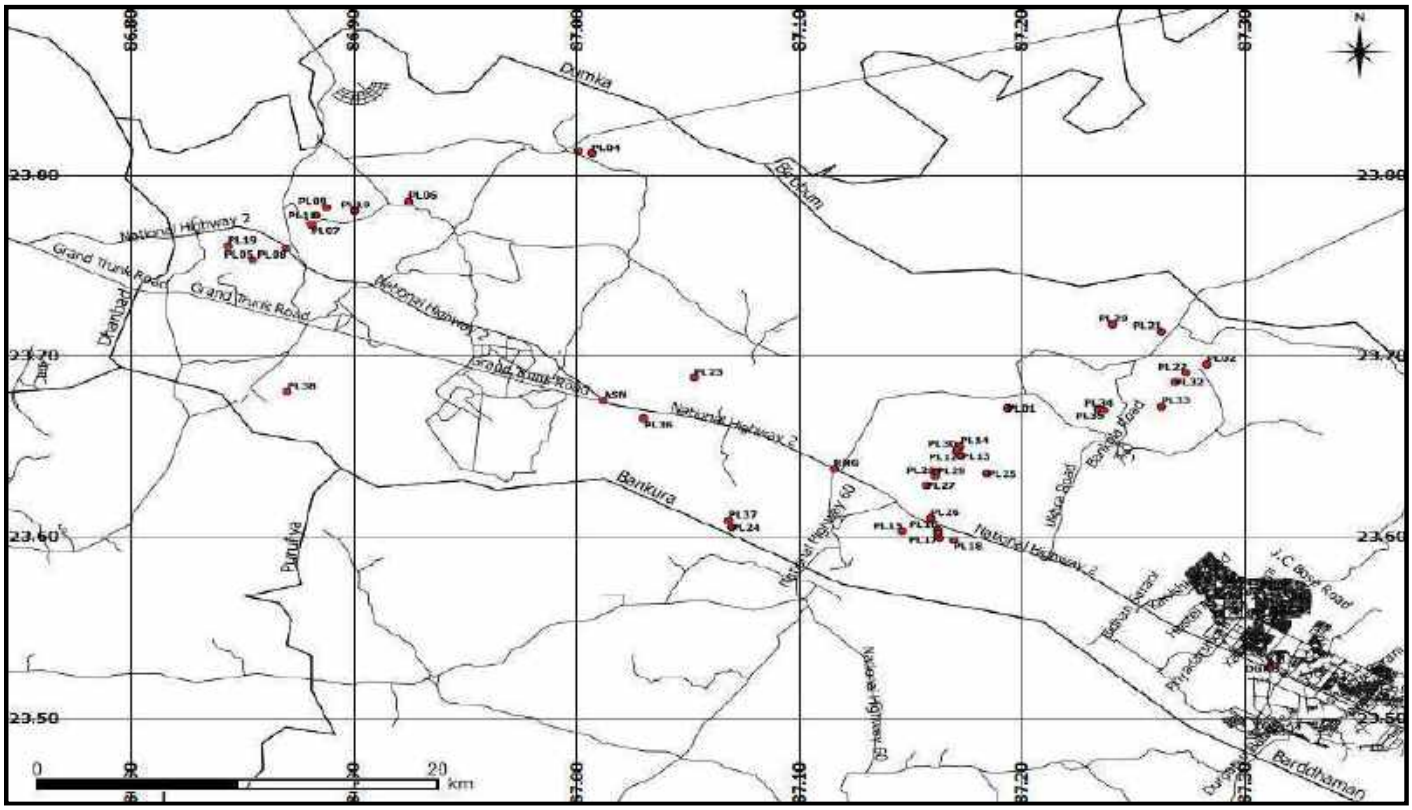

Figure 1. Distribution of Pitlakes in Raniganj Coal Field, West Bengal [Scale: 1:200,000]

[CODE USED: PL01-CHORA PITLAKE, PL02-JOYALBHANGA PITLAKE 1, PL03-VATAS PITLAKE, PL04-KATAPAHARI PITLAKE, PL05-AMDIA PITLAKE, PL06-SAMDI PITLAKE, PL07-DALMIA PITLAKE, PL08-BAMNA PITLAKE, PL09-BONBEDI PITLAKE, PL10-ALKUSAGOPALPUR PITLAKE, PL11-SIKHDASPUR PITLAKE, PL12-JAMBAD PITLAKE 5, PL13-JAMBAD PITLAKE 4, PL14-JAMBAD PITLAKE BOTTOM UP, PL15-WESTERN KAJORA PITLAKE, PL16-ATEWAL PITLAKE, PL17-KHADAN KALI PITLAKE, PL18-BABUISOL SIBMANDIR PITLAKE, PL19-RAMNAGAR PITLAKE, PL20-BELPAHARI KOTTADIHI PITLAKE, PL21-DALURBANDH PITLAKE, PL22-NAGRAKONDA PITLAKE, PL23-PATHALDANGA PITLAKE, PL24-NIMCHA HARABANGA PITLAKE, PL25-REAL KAJORA PITLAKE, PL26- CHAKRAMBATI PITLAKE, PL27-DHANDERDIHI PITLAKE 1, PL28-DHANDERDIHI PITLAKE 2, PL29-DHANDADIHI PITLAKE 3, PL30-PORASIA KHADAN PITLAKE, PL31-BABUISOL COLONY PITLAKE, PL32-KUMARDIHI PITLAKE, PL33-KUMARDIHI OLD OCP PITLAKE, PL34-JOYALBANGA PITLAKE 2, PL35-SANKARPUR PITLAKE, PL36-GUNJAN ECOLOGICAL PARK PITLAKE, PL37-NIMCHA DAMALI HARABANGA PITLAKE, PL38-PATMOHANA RANISAYAR PITLAKE]

Among the various practices, different food source collection (e.g. trapa cultivation, edible vegetables, fishes, fruits) comprised the major use (35 pitlakes, 92.11%) followed by fodder use (19, 50%) and thatching material use (13, 34.21%). One of the vital resource of these pitlakes is 'water' and we observed proper and well-organized water supply system in 11 pitlakes (28.95%). Drinking water use and vehicle washing were the less frequent practices in these pitlakes (9, 23.68%) which were performed in selected pitlakes only.

CCA or Canonical correspondence analysis assessed the pattern of pitlakes' usages (between the pitlakes' use data with pitlakes ecological characters i.e mean depth, age, elevation and magnitude of usages (i.e Multipurpose use of pitlakes).Table 2 depicts the Eigen values and percentages of inertia derived from CCA. Fig 3 depicts the Scree plot of CCA analysis in which F1 (79.56%) and F2 (17.06%) axes together explain the most constrained inertia 96.63%. The biplot of the first two canonical axes (eigenvalues 0.044 and 0.009 respectively) is shown in Fig 4. The first two axes of the CCA explain 96.63% of the variance of the 'ecological character- use pattern relationship' in these pitlakes.

Table 2. Eigen values and percentages of inertia derived from CCA.

	F1	F2	F3
Eigenvalue	0.0441	0.0095	0.0019
Constrained inertia (%)	79.5627	17.0658	3.3715
Cumulative %	79.5627	96.6285	100.0000
Total inertia	45.3428	9.7258	1.9214
Cumulative % (%)	45.3428	55.0685	56.9900

Table 3 depicts the weighted averages of CCA scores of different usages of pitlakes. It was revealed that Recreational fishing (0.8906), Food source use (0.8874) and Domestic use (0.8721) were the highly performed practices in these pitlakes based on the ecological attributes. Similarly Irrigational use (0.1881), Vehicle washing (0.2927) and Drinking water use (0.3005) were the practices performed in less magnitude. According to the CCA, it was observed that there is a prevailing pattern/trend of use pattern by local stakeholders. Pitlakes with older age are used as food source (0.9251) followed by recreational fishing (0.9212) and domestic use (0.9078) by the inhabitants in surrounding villages.

In this regard we observed that newly formed pitlakes are not preferred for irrigational use (0.2143), drinking water (0.2443) and livestock bathing purpose (0.2585) by the stakeholders. Depths of pit lakes appreciably direct different uses such as there is a trend to use Pitlakes with lower depth in greater magnitude. Recreational fishing (0.8796), food source use (0.8551), domestic use (0.8510) and aesthetic use (0.7204) are some of the notable usages which were exclusively found in pitlakes with lower mean depth of water column. Whereas deeper pitlakes were used for mostly irrigational use (0.1429), vehicle washing (0.2980) and water supply (0.4061).

From the CCA, it was revealed that five uses are performed in efficient way in a mean elevation (89.9 meter) gradient, which includes fodder use (0.5252), piscicultural use (0.4678), religious use (0.3981), thatching material use (0.3714) and livestock bathing use (0.3099). Multipurpose use of pitlakes were performed in higher magnitude with food source use followed by recreational fishing use, domestic use, aesthetic use, fodder use, piscicultural use, religious use and thatching material use (CCA scores >0.4000). These seven activities are performed in different combination among different pitlakes by local stakeholders especially villagers. Whereas pitlakes attributed with one or two practices includes the following usages: irrigational use, water supply use, drinking water use, vehicle washing, and live stock bathing (CCA scores <0.4000).

The overview of land cover around pitlakes is depicted in Figure 4. Total three predominant landforms namely Built up, Kharif and water bodies are observed around the study sites. The buildup landforms chiefly include the urban and semiurban areas of Durgapur, Asansol, Raniganj, Ukhra, Andal Barakar and Pandabeswar. The general agricultural landform in this area are included various Kharif crops which chiefly include Aman paddy. Around the pitlakes surface water resources predominantly included two major component. On the southern part River Damodar flows North West to south East direction followed by Ajoy in the Northern part of the studied pitlakes. These rivers are rainfed and during the summer season the requirement of water source mainly for agricultural purpose could be fulfilled by large volume of good quality water stored in these pitlakes.

Table 3. Weighted averages of CCA scores of different usages of pitlakes.

Pitlake usages	Age of Pitlakes	Mean Depth	Elevation	Multiple use Of Pitlakes	Global Weighted Means
Piscicultural Use	0.4760	0.4388	0.4678	0.5366	0.4566
Recreational Fishing Use	0.9212	0.8796	0.8913	0.9431	0.8906
Irrigational Use	0.2143	0.1429	0.2308	0.2846	0.1881
Domestic Use	0.9078	0.8510	0.8834	0.9309	0.8721
Livestock Bathing Use	0.2585	0.3041	0.3099	0.3659	0.3021
Religious Use	0.3980	0.3796	0.3981	0.4959	0.3916
Drinking Water Use	0.2443	0.3490	0.2565	0.3130	0.3005
Aesthetic Use	0.7029	0.7204	0.7468	0.8130	0.7304
Vehicle Washing Use	0.2837	0.2980	0.2868	0.3252	0.2927
Food Source Use	0.9251	0.8551	0.9123	0.9472	0.8874
Thatching Material Use	0.3105	0.3408	0.3714	0.4228	0.3505
Fodder Use	0.4744	0.4245	0.5252	0.5935	0.4725
Water Supply Use	0.3302	0.4061	0.3086	0.3049	0.3577

DISCUSSION

During this entire tenure of work a very brief idea about the current scenario of the pitlakes in this region is generated for the first time. Further extensive research, investigation, seasonal monitoring, pilot scale study with socioeconomic purview in the next phase of study will produce valuable research findings. However, recent investigations on aquatic systems have highlighted the fact of continued decline in aquatic species and degradation of wetland and freshwater habitats across the world [32]. One of the reasons for human failure to use the natural environment and resources of freshwater ecosystems in a sustainable way is because the long-term benefits to be derived from such sustainable use are not always as obvious as the perceived short-term benefits from economic development which destroys or damages the freshwater habitat. Thus, Ecological restoration and ecosystem management is an essential component of any habitat conservation.

Pit lake ecosystems are not only ecologically threatened and critical aquatic landscapes but also a source of potential biological resources for the future. They support rich biodiversity, high abundance of animal and plant species, many of them threatened on a local or worldwide basis [33]. The lack of knowledge on pit lakes continues to hinder their proper management which is also observed under the present investigation. Wetland and freshwater systems such as Pit lake are important for the provision of environmental and ecological services [34] in developing countries, that result from their varied bio-geo-chemical functioning, ranging from fresh water to provision of services economically useful to human populations: for example food provision from fishing, and income generation via eco-tourism.

The present work would have valuable practical applications since pit lakes play an important role in the ecosystem functioning and hydrology of the area. They provide habitat for migratory birds, fisheries, water plants, animals and microbes. In view of this, the present work is of clear importance especially for policy designers. The findings of UPAR1 would contribute to the following outputs for conservation of Pitlakes in RCF-WB :

1) This revealed the current condition of the pit lakes of the target region, but also provide necessary guidelines for implementation of pit lake management/ livelihood generation programmes for the benefit of stakeholders inhabiting the area.

2) After successful completion of this research study, it is now possible to provide data on the ecology, biodiversity and environmental values of the pit lakes in RCF-WB. The research thus contributed to the development of decision support systems (DSS) for better conservation, management and sustainable use of wetlands to promote the key message of the Ramsar Convention's (1971) mission to achieve "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

3) The central theme of this work was basically Inventory and Assessment of RCF-WB pit lakes for Valuation, Management and Sustainable-Wise Utilization in fiture which has interdisciplinary implications and relevance. Agencies like MoST, MoEFCC, Department of Environment (WB), NBA, FRI, WWF, NGO, IUCN, BSI, ZSI, NBGRI, NRLM, Pollution control Board, State Department of Fisheries, Agriculture, Health, Science and Technology, DRDA, Land reforms, Irrigation, Forest, West Bengal Biodiversity Board etc can now use the outputs of this work to help inform and improve their approach to conservation and sustainable use of these critical landscapes. Authorities like Municipality, BDO, Panchayat, P.H.E, PWD etc. would also find application of the present work in ecological and economic welfare of the place through effective collaboration.

4. ACKNOWLEDGMENTS

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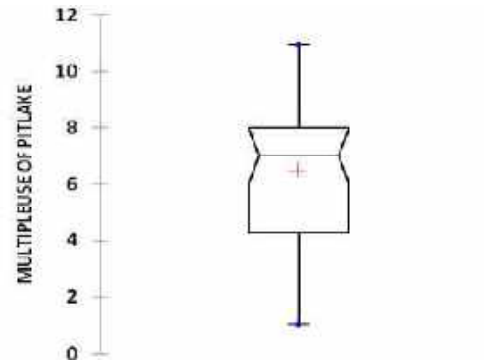

Figure 2. Boxplot showing the multipurpose use frequency in pitlakes.

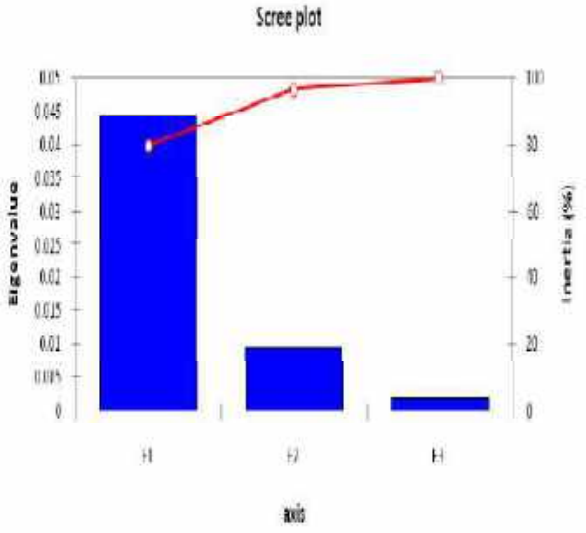

Figure 3. Scree Plot of F1, F2 and F3 axes derived from CCA.

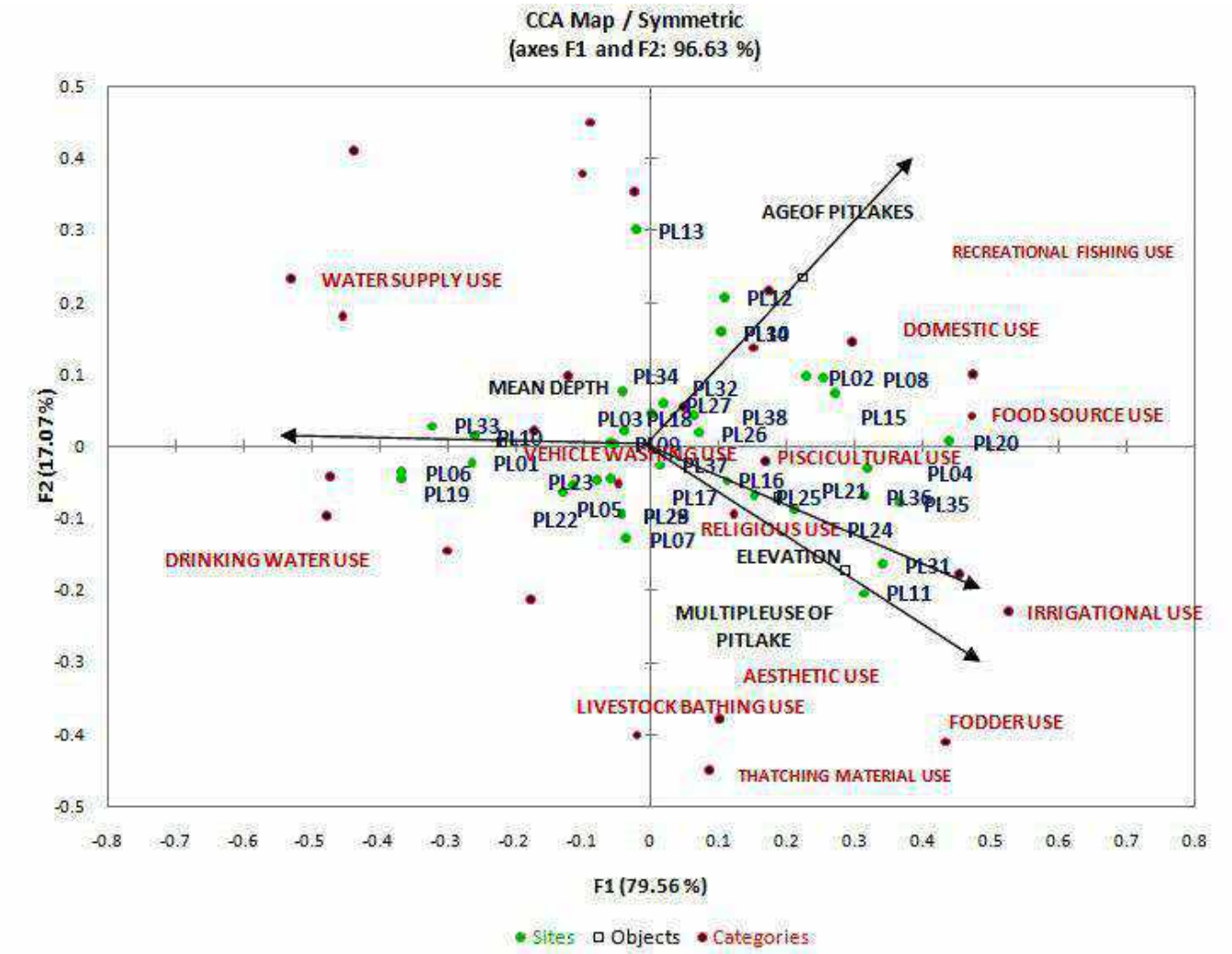

Figure 4. Symmetric graphical display in two dimensions resulting from the CCA of survey data. The percentage of inertia accounted for by the two dimensions is 96.63%. [CODE USED: PL01-CHORA PITLAKE, PL02-JOYALBHANGA PITLAKE 1, PL03-VATAS PITLAKE, PL04-KATAPAHARI PITLAKE, PL05-AMDIA PITLAKE, PL06-SAMDI PITLAKE, PL07-DALMIA PITLAKE, PL08-BAMNA PITLAKE, PL09-BONBEDI PITLAKE, PL10-ALKUSAGOPALPUR PITLAKE, PL11-SIKHDASPUR PITLAKE, PL12-JAMBAD PITLAKE 5, PL13-JAMBAD PITLAKE 4, PL14-JAMBAD PITLAKE BOTTOM UP, PL15-WESTERN KAJORA PITLAKE, PL16-ATEWAL PITLAKE, PL17-KHADAN KALI PITLAKE, PL18-BABUISOL SIBMANDIR PITLAKE, PL19-RAMNAGAR PITLAKE, PL20-BELPAHARI KOTTADIHI PITLAKE, PL21-DALURBANDH PITLAKE, PL22-NAGRAKONDA PITLAKE, PL23-PATHALDANGA PITLAKE, PL24-NIMCHA HARABANGA PITLAKE, PL25-REAL KAJORA PITLAKE, PL26- CHAKRAMBATI PITLAKE, PL27-DHANDERDIHI PITLAKE 1, PL28-DHANDERDIHI PITLAKE 2, PL29-DHANDADIHI PITLAKE 3, PL30-PORASIA KHADAN PITLAKE, PL31-BABUISOL COLONY PITLAKE, PL32-KUMARDIHI PITLAKE, PL33-KUMARDIHI OLD OCP PITLAKE, PL34-JOYALBANGA PITLAKE 2, PL35-SANKARPUR PITLAKE, PL36-GUNJAN ECOLOGICAL PARK PITLAKE, PL37-NIMCHA DAMALI HARABANGA PITLAKE, PL38-PATMOHANA RANISAYAR PITLAKE]

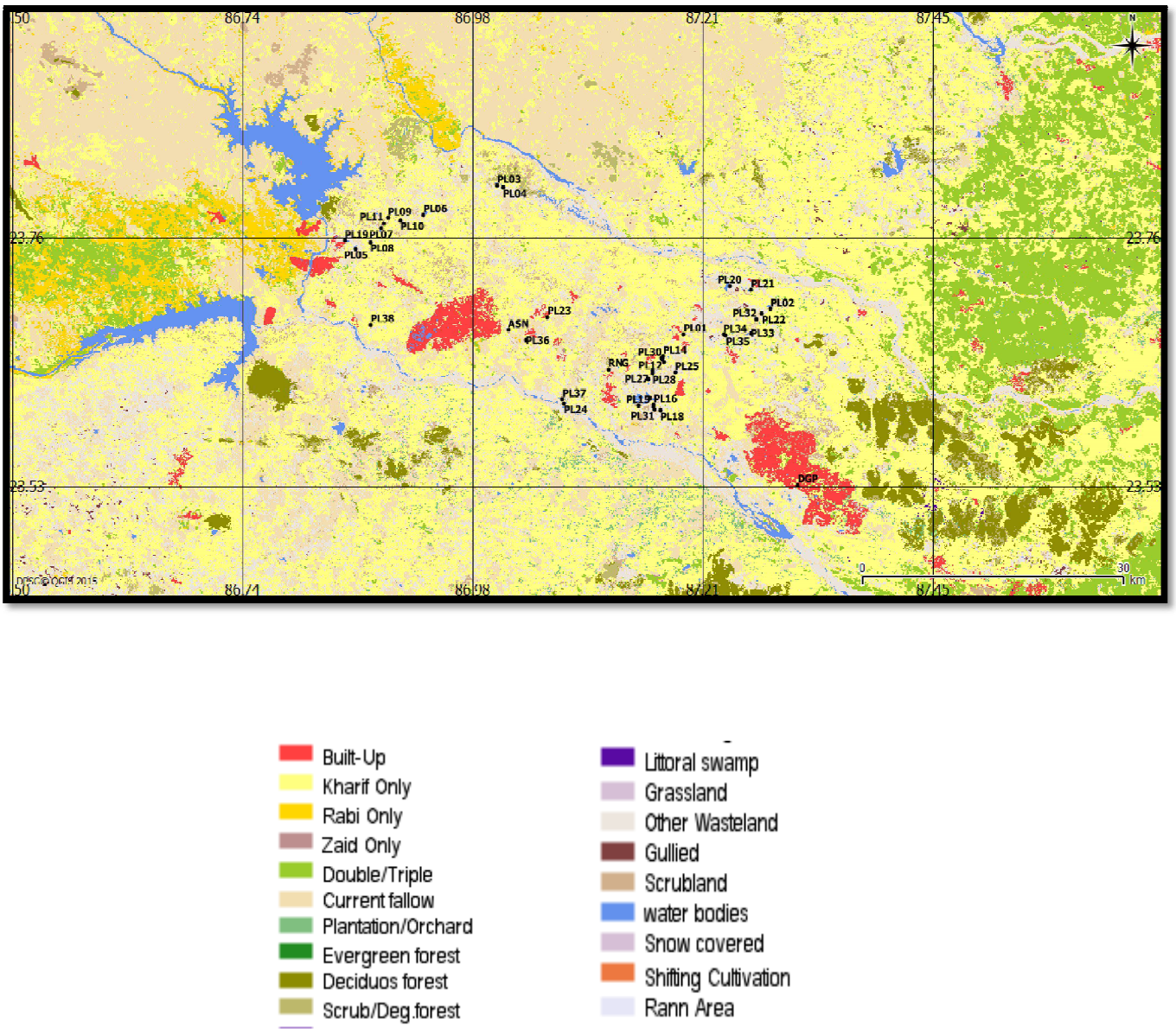

Figure 4. Current Land cover pattern around RCF-Pitlakes. [CODE USED: PL01-CHORA PITLAKE, PL02-JOYALBHANGA PITLAKE 1, PL03-VATAS PITLAKE, PL04-KATAPAHARI PITLAKE, PL05-AMDIA PITLAKE, PL06-SAMDI PITLAKE, PL07-DALMIA PITLAKE, PL08-BAMNA PITLAKE, PL09-BONBEDI PITLAKE, PL10-ALKUSAGOPALPUR PITLAKE, PL11-SIKHDASPUR PITLAKE, PL12-JAMBAD PITLAKE 5, PL13-JAMBAD PITLAKE 4, PL14-JAMBAD PITLAKE BOTTOM UP, PL15-WESTERN KAJORA PITLAKE, PL16-ATEWAL PITLAKE, PL17-KHADAN KALI PITLAKE, PL18-BABUISOL SIBMANDIR PITLAKE, PL19-RAMNAGAR PITLAKE, PL20-BELPAHARI KOTTADIHI PITLAKE, PL21-DALURBANDH PITLAKE, PL22-NAGRAKONDA PITLAKE, PL23-PATHALDANGA PITLAKE, PL24-NIMCHA HARABANGA PITLAKE, PL25-REAL KAJORA PITLAKE, PL26- CHAKRAMBATI PITLAKE, PL27-DHANDERDIHI PITLAKE 1, PL28-DHANDERDIHI PITLAKE 2, PL29-DHANDADIHI PITLAKE 3, PL30-PORASIA KHADAN PITLAKE, PL31-BABUISOL COLONY PITLAKE, PL32-KUMARDIHI PITLAKE, PL33-KUMARDIHI OLD OCP PITLAKE, PL34-JOYALBANGA PITLAKE 2, PL35-SANKARPUR PITLAKE, PL36-GUNJAN ECOLOGICAL PARK PITLAKE, PL37-NIMCHA DAMALI HARABANGA PITLAKE, PL38-PATMOHANA RANISAYAR PITLAKE]

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