Urban Agroecosystems in Dynamic Yamuna River Sandbars in Delhi, Capital City of India

Pulak Das[1]

1 Ambedkar University Delhi

Funding: Dr. B.R. Ambedkar University Delhi

Potential competing interests: No potential competing interests to declare.

Abstract

Present paper studies urban agroecosystems on Yamuna River sandbars (islands) in Delhi using GIS. These sandbars formally come under local administration and are used by people for different activities like agriculture, fishing, collection of various types of grasses, and grazing of livestock. Cheap laborers from different states of India migrate to the sandbars for seasonal employment. The crops grown by farmers include tomatoes, pumpkins, bottle gourds, ridge gourds, and bitter gourds. Tomatoes are grown on the maximum area of land on the sandbars. The products are sold at different nearby markets according to requirements. These small and fragile agroecosystems have inputs like seeds, human labor/hours, fertilizers, water, fuels, etc., and outputs like crops, grasses, fish, milk, etc. For a long time, people have been interested in these landscapes because; i) the deposits along the Yamuna are fertile and therefore appropriate for farming, (ii) the growth of natural vegetation/fodder species (which includes many types of grasses) makes them good pastures, (iii) the river banks along the attached sandbars provide space for the washermen, (*dhobi-ghat)*, (iv) even if the government officials abandon the slums/activities on these sandbars, the people involved in them could re-build it in no time, and (v) none of the sandbar dwellers were paying any rent/lease for the activities they are carrying out on the sandbars. The pastoralists (*gujjar)* do not seem to have to pay anything to the claimant. On the other hand, the farmers do have to pay for cultivating on the sandbars.

Pulak Das

School of Human Ecology,

Dr. B.R. Ambedkar University Delhi

Kashmere Gate, Lothian Road, Delhi-06

www.aud.ac.in

Email: pulakdas.ecology@gmail.com; pulak@aud.ac.in

Keywords: Agroecosystems; GIS; sandbars; urban; Yamuna river, Delhi.

Introduction

During the process of erosion and sedimentation, new fragile lands emerge between the flow channels and banks of some rivers. These lands are called channel deposits, channel bars, or sandbars. These channel bars do not remain stable and normally have a longitudinal migration. They emerge, submerge, and re-emerge continuously [1]. Vegetation succession on channel bars can increase the stability of these semi-stable lands [2] and take the form of a riverine island. In the middle Ganga plains of eastern Uttar Pradesh and the Bihar states of India, these islands are known as *Diaras* and are made of coarser sands and gravels [3]. In the Indus plains in Pakistan, these lands are described as *Kuchha* (wet and fragile, as opposed to *Pucca*, or more permanent lands) and *Baet* (rising like mounds between the two branches of rivers). In Bengal, the northeastern states of Assam and Tripura, and in Bangladesh, these are called *Chars (Charlands)* or river islands [3]. The Yamuna is one of the important rivers in India along which lie cities of the greatest historical and cultural importance. The river enters the National Capital Territory (NCT) of Delhi at Palla in the north and exits at Jaitpur in the south, travelling a distance of around 52 kilometres within Delhi. Like many other rivers, sandbars are observed within the river Yamuna, and its banks also. It is evident from satellite imageries, field observations, and various studies that these shifting channel deposits support numerous agroecosystems and socio-economic activities along its stretch within and near the NCT of Delhi ([4][5][6][7][8][9]).

Sandbars are found both in the braided river and meandering river channels. A floating sandbar is completely surrounded by water and is away from the mainland, while an attached sandbar remains attached to the mainland. Although transient in nature, these sandbars are very fertile due to the occurrence of frequent floods, and they support populations and agriculture. People residing on or dependent on these sandbars are vulnerable and therefore do suffer from loss of life and livelihood due to the flood and dynamic nature of these lands. The socio-economic activities supported by the sandbars are fishing, farming, pastoralism, grazing, and collection of different types of grass. River sandbars are dynamic in terms of area covered, both through reduction and increase across time. For example, the sandbar areas in the Brahmaputra River in Assam increased by 23% during 1988 to 2018 [10]. The suitability of sandbars as agricultural land depends on various factors such as flow pattern, seasonality, location, bridges on the river, river training works, particle size, nutrient richness, etc. [11].

Urban agriculture is available in various lands worldwide, such as school grounds, housing facilities, rooftops, vacant lands, etc. [12][13]. Urban agroecosystems also involve private gardens, urban farms, orchards, and community gardens [14]. Various ideas are also observed, such as urban food forests, urban agroforestry, permaculture gardens, etc. [15]. Agroecosystems in urban lands have the potential for meeting human needs along with other ecosystem services [15]. Urban agriculture is seen as a sustainable alternative to increase food security, considering increases in food prices, increasing energy costs, demographic pressures, and corporatisation of food markets. [16]; [17]. In urban agroecosystems, focussing on agricultural yield only, however, often overlooks inequitable food access and other associated challenges which are a result of historic faults such as pollution and soil contamination, land access and tenure systems, developmental pressure, etc., among others [18]. Such a conventional way of defining urban agriculture often fails to identify the problems within the system [19].

Urban agriculture would require thirty percent of the total urban area to meet the global demand for vegetables, which is not possible due to land tenure systems and urban sprawl issues [20][21]. Urban river sandbars may play a major role in providing the additional land across the globe. As estimated by De Zeeuw et al. [22], a city with 10 million people or more, over 6,000 tons of food has to be imported every day, traveling an average of 1,000 miles. Delhi's population is roughly around 20 million. The present paper studies these agroecosystems on some of the Yamuna River sandbars/islands in two locations in Delhi using GIS. These sandbars legally come under the local administration and are used by people for different activities like agriculture, fishing, collection of various types of grasses, and grazing of livestock.

Materials and Methods

Study area

Two sites – site 1, near Kashmere Gate Inter-state Bus Terminus (ISBT) flyover, and site 2, near Yamuna Bank Metro bridge – are selected (Figs. 1, 1(b)) for the study. At each site, two channel deposits were considered for the study. These selections are based on a number of reconnaissance surveys, study of Google Earth imageries, presence of houses, existence of various livelihood activities, accessibility of these sandbars, and existing literature on the Yamuna and sandbars in the region and other areas.

Methodology

The study was conducted during the year 2016, and the methodology involved using a semi-structured questionnaire to get the relevant information about the resource extraction and livelihood practices of the people dependent on the sandbars. Focus group discussions (FGDs) were used to find out the relevant information – more than 20 FGDs were conducted among various people. Many formal and informal meetings were also done along with participant observation. A hand-held GPS unit was used to take coordinates of relevant points. Field coordinates and Google Earth imageries were used in the ArcMap environment of ArcGIS software for mapping resource extraction and change detection. Secondary data was studied from various research articles, published reports, and various other documents on the related topics for a better understanding of the existing property rights, socio-economic activities, agroecosystems, and the dynamicity of the channel deposits.

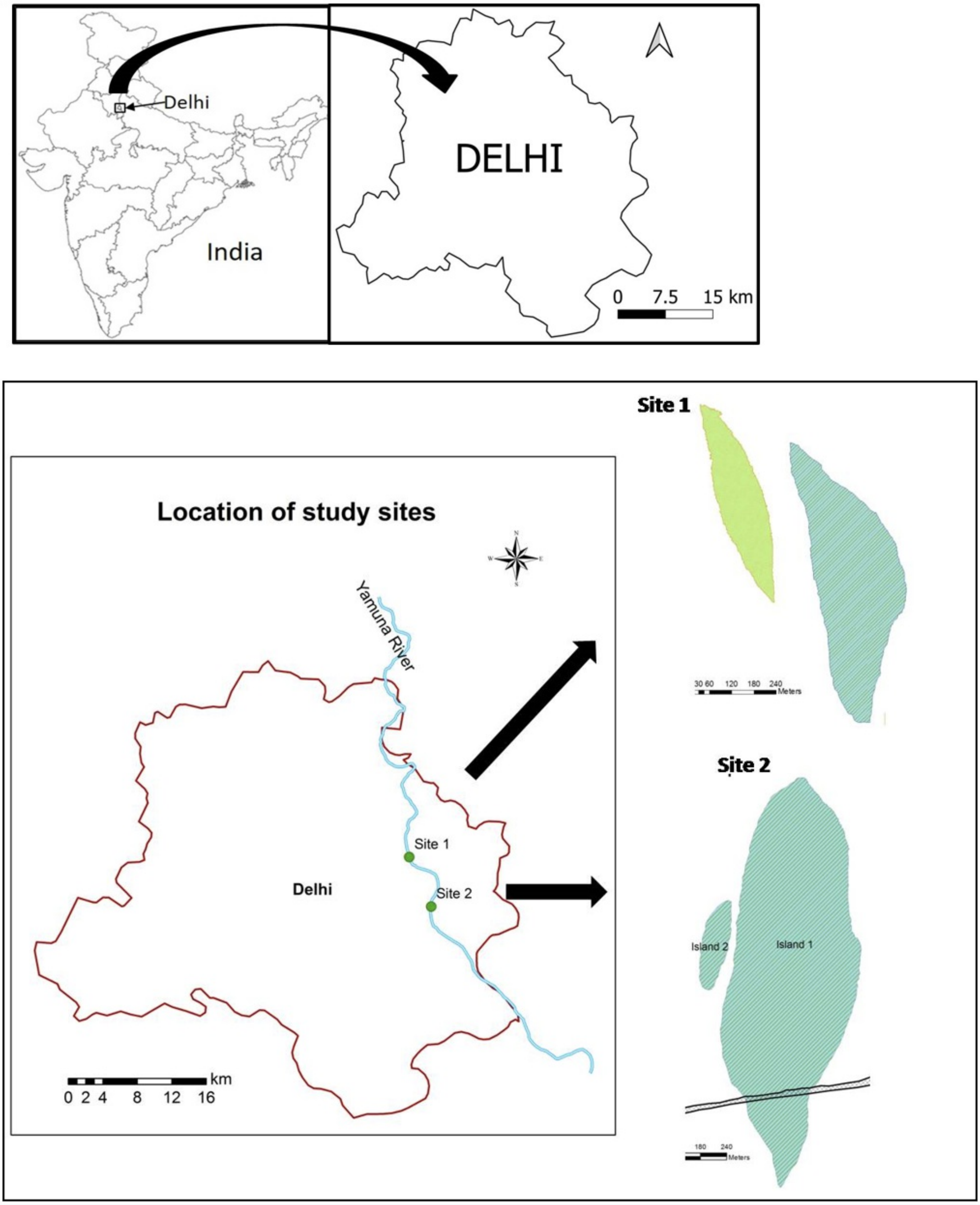

Fig.1a. The study sites in River Yamuna in Delhi

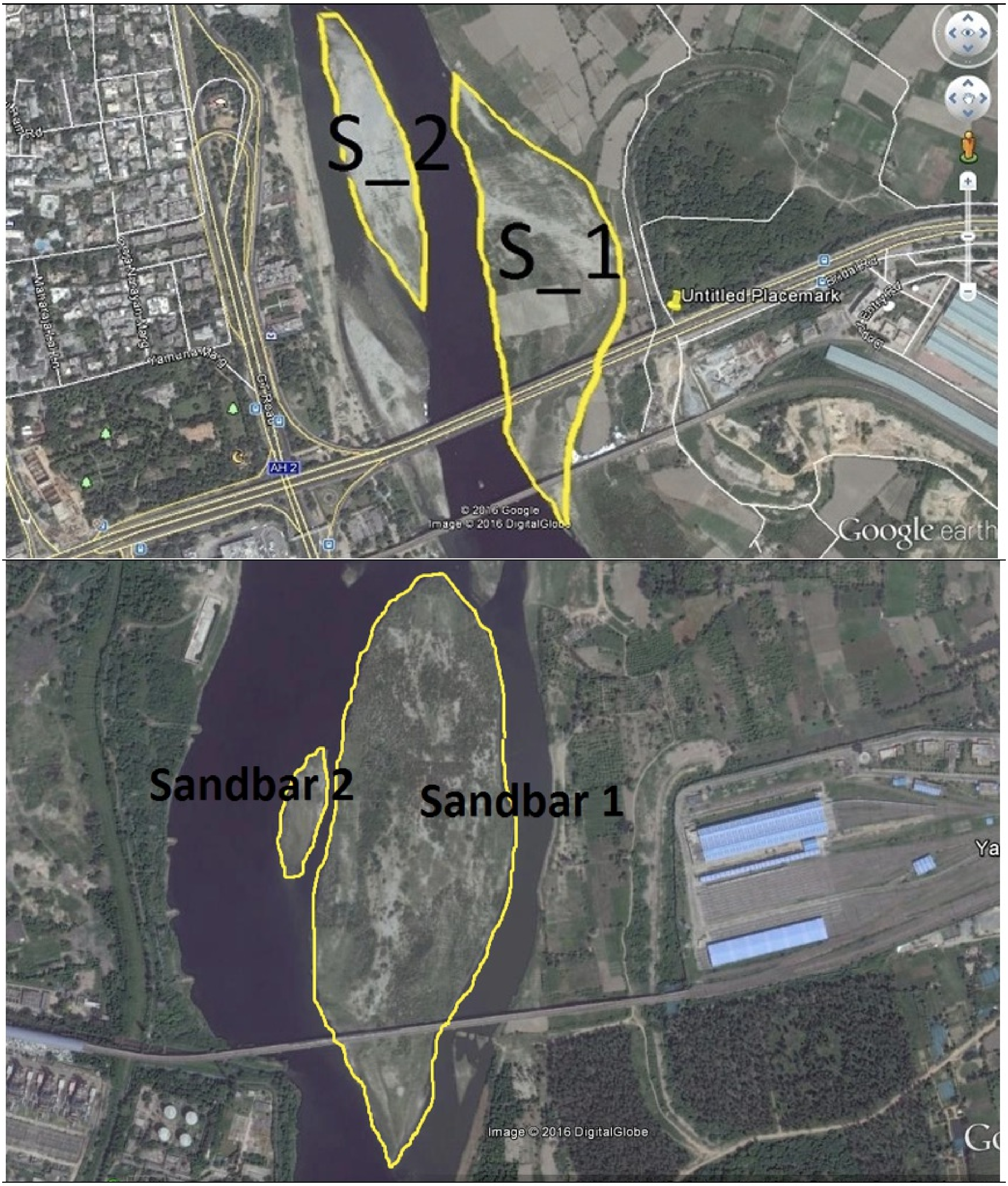

Fig.1b. The study sites in River Yamuna in Delhi

Results

Spatio-temporal dynamics of channel deposits

Site 1

The channel deposits have showed a change in area from 43.5 acres in 2006 to 23.7 acres in 2016 (Fig. 2). This decrease, although not gradual, first showed a rise till 2010, up to 46.8 acres, and gradually decreased to 17 acres in 2013. From 2013 till 2016, the overall area increased. The southern sandbar in 2016 was not completely attached to the right bank till 2012-2013 when it started coming towards the bank. After the last massive floods in the Yamuna River in 2013, this completely attached to the bank, and a new, comparatively smaller bar emerged parallelly towards the upper left side, roughly around the first half of 2014.

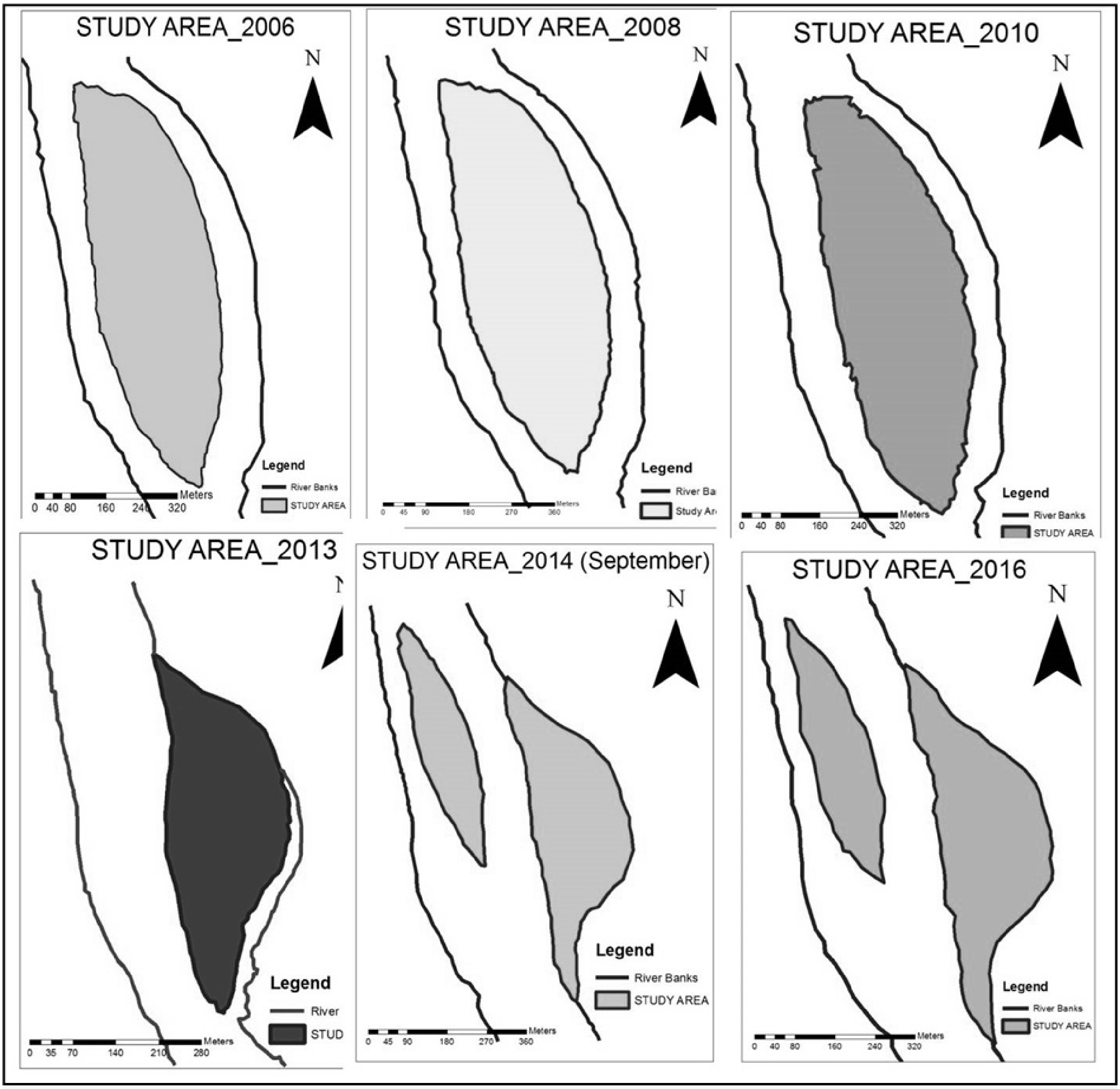

Fig.2. Spatio-temporal dynamics of channel deposits between 2006 and 2016 at site 1

Site 2

The channel bars encountered many changes both spatially and temporally between 2006 and 2016 (Fig. 3). From around 6-8 bars between 2006 and 2010, there were only two bars in 2016. The area coverage also changed from around 44.7 acres to 51.4 acres in 10 years. In 2006, the study area was divided into fragments, and there was a difference in its shape as compared to the present study area. In 2006, the shape was quite irregular. The channel deposit was near the right bank of the river. The sandbar was much closer to the ITO Bridge towards the top of the island – north side of it. The larger island had much smoother boundaries than the small islands. The shape of the channel deposit was broader towards the upper and narrower towards the lower side.

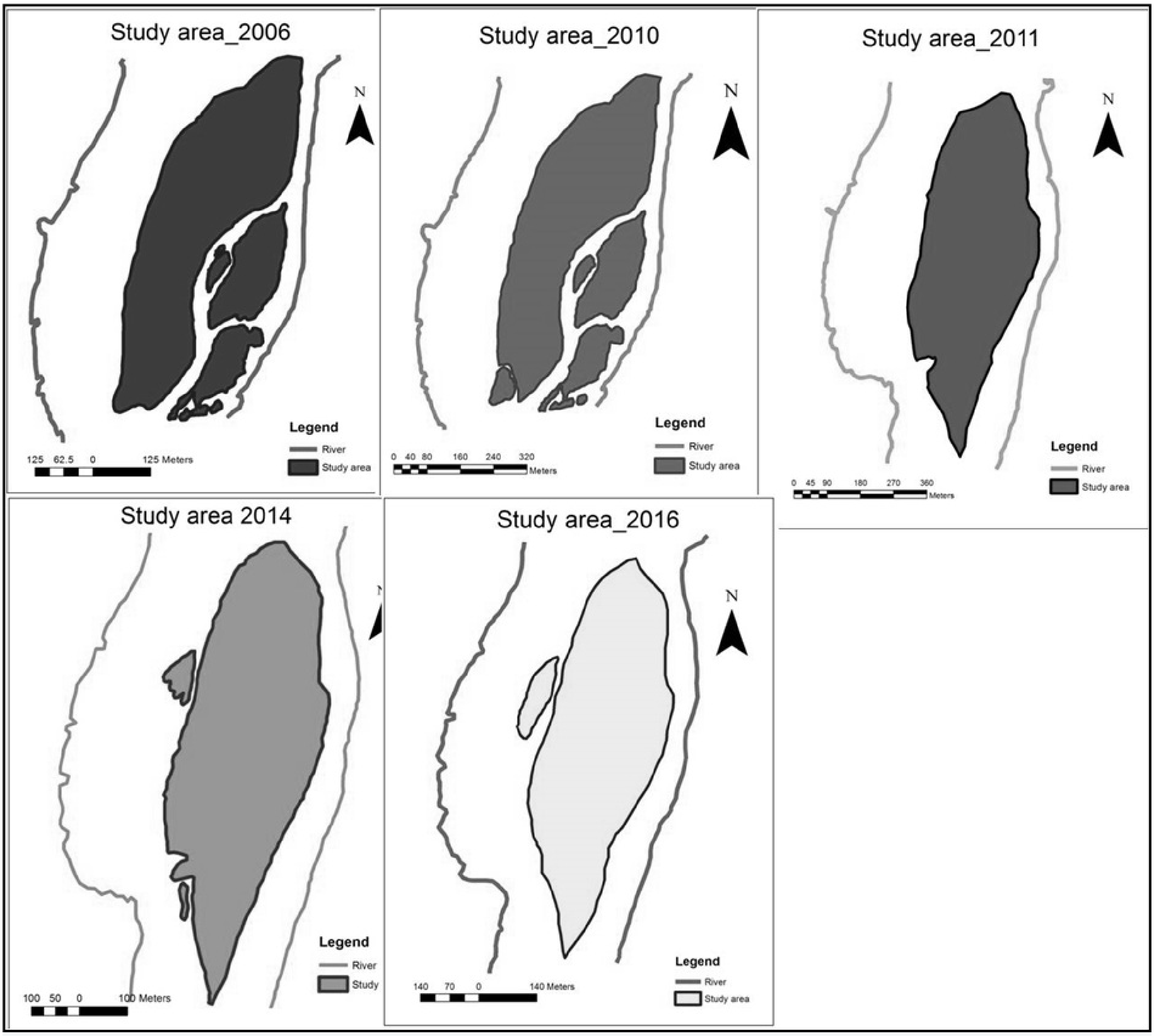

Fig.3. Spatio-temporal dynamics of channel deposits between 2006 and 2016 at site 2

Governance of channel deposits

Site 1

The sandbars under study had a tenure system until 2014, particularly the land that was not attached to banks. That was the time when there were around 20-22 farmers practicing agriculture on the attached part of the sandbars for the last 20 years. Delhi Peasants Co-operative Multipurpose Society Ltd. (Table 1) used to give land on lease to them, and each received patches of different sizes/expanse on the sandbars for agricultural purposes. The sandbars attached to banks were leased out by a community called *Gujjars*. Out of these 20-22 farmers, some used to take land for farming from both of them, i.e., the Society and the *Gujjars*. The land they used to get from the*Gujjars* was situated on the mainland and was for Rs.2000-3000 per bigha. Whereas, the land they got from the society was situated in the sandbar area, and the lease/rent amount for the floodplains was Rs.1000 per bigha.

Table 1. Differences in governance between the society and the *Gujjars*

Criteria	The Society	*Gujjars*
Area of operation	Floodplains of the sandbars, the ones attached to the mainland	Only the area on the mainland
Lease/rent amount	Rs.1000/Bigha	Rs.2000-3000/Bigha
Location of tenants/farmers	Only those tenants/farmers were members who used to cultivate the sandbars	Farmers from both the sandbars and the mainland were taking land from them
Type of tenants/farmers	Permanent; since each season the same members used to take land	There were no such permanent members. Whoever gave them a good amount for their land, the land was given to them only.
Legal document	Used to provide a legal receipt	They never gave any legal document/receipt to their tenant farmers, which the farmers could claim for their rented land.
River island/floating sandbar	The newly emerged river island/floating sandbar used to belong to the society only.	They had no property rights over such kind of newly emerged river islands.

Site 2

It is observed that there is a role of middlemen or *'claimants'* who lease out the channel deposits to people for various uses. These middlemen are apparently powerful, wealthy, and elite, and since they live near these unstable, newly emerged sandbars, they claim a sort of ownership of them. Delhi Development Authority (DDA) seems to pay some compensation to these claimants for the crops and seeds that are planted there, although they do not compensate for the land, as the land belongs to DDA. The *claimants* seem to decide the price of the sandbar after inspecting (if the area of the sandbar has increased or decreased) the land area in October. They examine the area of the land and accordingly raise or lower the price of the land for the farmers. Other users of the sandbars, such as those who collect grass of *Jhau* which is available here, also pay a fixed monthly amount of Rs 2000/month to these middlemen.

Agroecosystems in Channel Deposits

Agriculture

Site 1

There are two sandbars, one is attached to the mainland, whereas the other one is a floating sandbar or a riverine island. Only two small patches are under cultivation on the bigger attached sandbar. However, a rather large area is being cultivated each year by the three families of farmers on the floating sandbar. Farming of mainly vegetables has been done on both the sandbars for around twenty years now. On the upper deposit, farming has been going on since 2014 (Fig. 4). For doing farming on these channel bars and to move to and fro, families had three boats with them, made out of thermocol. It is observed that large patches on these channel deposits are also seemingly barren, although patches of grasses were also observed. The families owned a small land area in the lower channel deposit, growing bottle gourd (*Louki*), ridged gourd (*Turai*), and tomato (*tamatar*) in front of their *katcha* houses. These are referred to as *'Palej'*. On the left-hand side channel deposit, families have owned an extended stretch of productive agricultural land area in the midst of the Yamuna River.

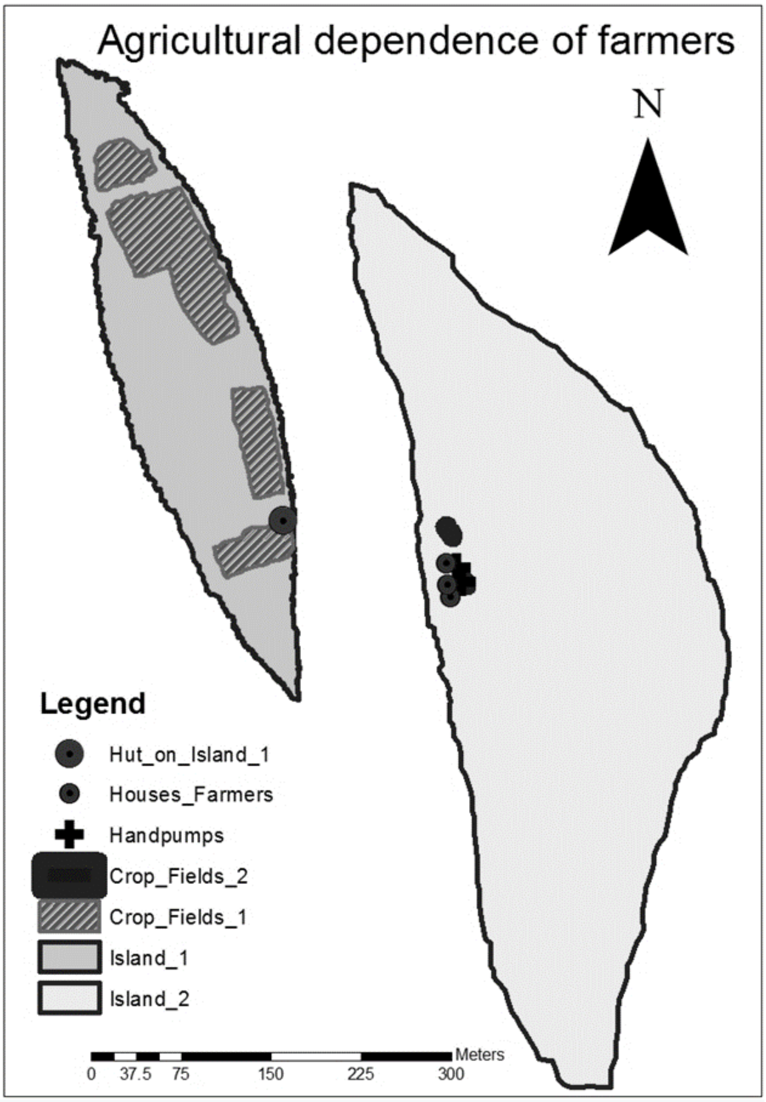

Fig.4. Farmers living on the sandbar and their agricultural dependence

The total area under cultivation in 2016 was around 8 acres. Overall, four major *Palej*' crops were grown, which include bottle-gourd (*Louki*), ridged gourd (*Turai*), bitter gourd (*karela*), and pumpkin (*Sitafal*). The maximum area was sown under bottle-gourd and ridged gourd. The cultivation of bitter-gourd was also moderate and was slightly lesser than that of the bottle gourd and ridged gourd. Whereas, the least area was given to the crop of pumpkin in the agricultural fields. The farmers refer to their crops as "*Chau masi fasal*" or "the crop of four months," since it requires only four months for their crops to get ready to be harvested. They grow only this type of crop because the rest of the months there remains a possibility of flood and rain, which could destroy their farms. The number of hours the farmer works in the crop fields varies and depends on the season and the type of work going on in that particular season (Table 2). The amount of land that is cultivated in a season depends on the economic condition of a family, i.e., how much they are capable of putting in the money in terms of seeds, fertilizers, and various other farm needs, and the number of family members that are available in that season to carry out farming. No external labours are used, and the dependence is entirely on family members. To buy seeds, fertilizers, insecticides, tools, etc., the farmers depend on '*arhatiya'*, the wholesale retailer in the wholesale market, who charges an extra 10 percent interest on the money lent by them. By lending this money, the farmers are bound to sell the harvested crop to that particular “*arhatiya*” only.

Table 2. Seasonal calendar of farming at site 1

Type of work	Months in which the work is being carried out.	Hours per day
Ploughing and watering	October, November, and December	8
Management of crops, spraying pesticides, removing weeds, spreading “kans” on the surface	January and February	5
Harvesting	March, April, and May	6
Harvesting	June	3

Site 2

In the study area, it was observed that the large part of the sandbar was used for the purpose of agriculture, which has been stable largely for the last five years. It was observed that two farmers were practising farming in the study area. One of the two farmers is living nearby, while the other lives 7 km away from the study area and commutes daily during the cropping season (October to May). The crops grown include pumpkin, ridged gourd, bitter gourd, bottle gourd, and tomato, which are grown together from October to December. One farmer cultivated (area a) around 20 acres in 2016, while the other farmer cultivated (area b) about 8 acres (Fig. 5). As observed, both farmers have devoted a maximum area (more than half) to the crop of tomato. External labours (who have come from other states) are used in farming in both cases. During the study period, around 80 labours were seen working in both the farms for ploughing and sowing, which ends in December, and for harvesting during March. The *arhatiya* plays a very important role for the farmers here also. He plays the role of moneylender cum trader.

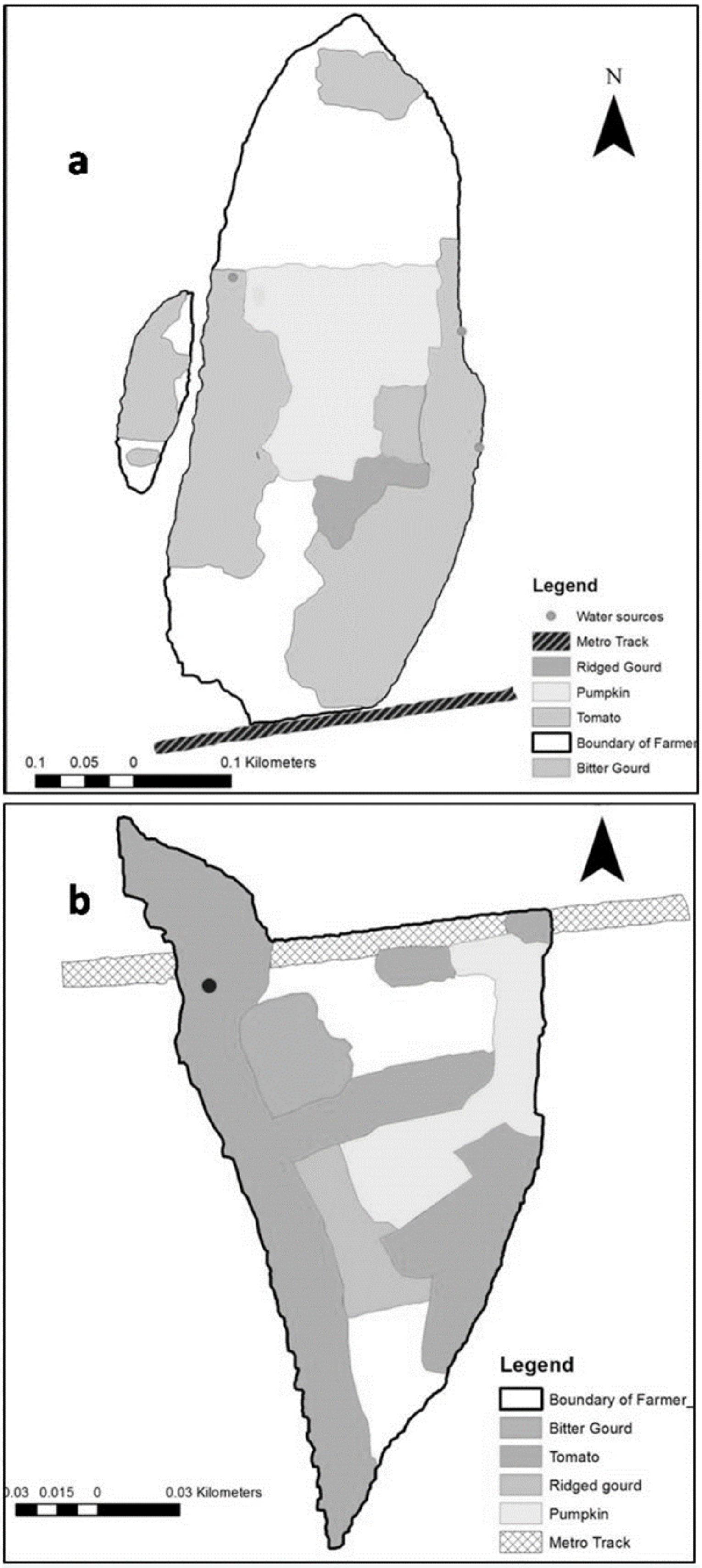

Fig.5. Two areas of farming (area a and area b) by two farmers

Livestock, pasture, and grasses

Site 1

Pasturage is the land which is used for pastures. But it's not always the case that they are visited/used by pastoralists only. There could be many types of people who could be rearing livestock and therefore be dependent on a particular land to graze them. The sandbars under study were also being visited by people who practice livestock rearing. The criteria of differentiation for the usage of the sandbars as pastures is based on the location; either they live on the sandbar or are from outside, rearing type (direct or indirect).

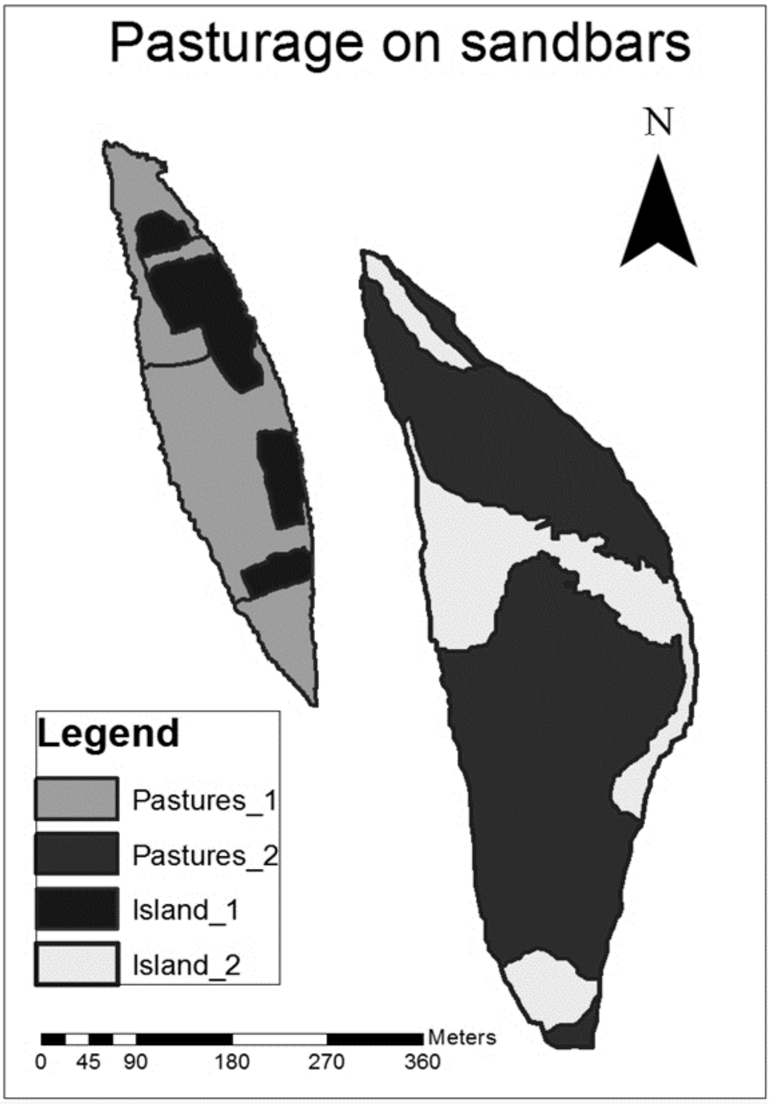

Fig.6. Pasturage observed in the study area (Site 1)

It is observed that the maximum usage of the sandbar, was done mainly by community involved in dairy farming (Fig. 6). The herd of cattles included cows, buffaloes, goats, and sheeps. The cattle can range from 35 to 45 numbers. Many types of grasses grow on their own after each rainy season and remains there until someone clears them up for some purpose. These include *Doob*, *Narsal*, *Kans*, *Khujri*, and *Jhau*. On an average cattle graze there for about 5-6 hours daily and supports the Dairy. The cattle also use the waterbodies for bathing and resting.

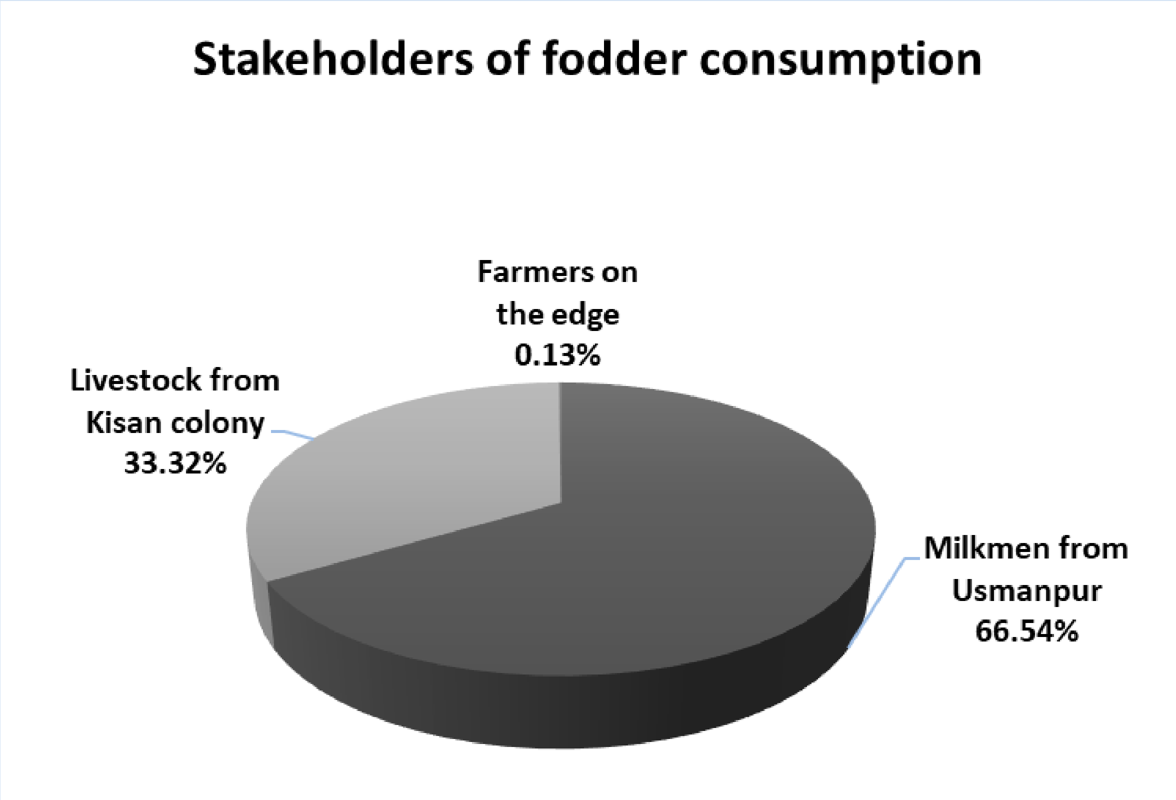

Fig.7. Fodder consumtion at site 1 by three groups of people

There are three stakeholders of pastures for livestocks (Fig.7); Milkmen from Usmanpur, People from Kisan colony, and Farmers living on the edge of the sandbar. The pasturage on the sandbar is being visited by very few (one or two) Gujjars (milkmen from Usmanpur) daily (except for the rainy season). Each one of them have around 35-45 cattle in total. This includes both cows and buffaloes. Cattles are not completely dependent on the pasturage of the sandbars for their milk production. Milkmen also purchase ready-made fodder for them. People from Kisan colony are also dependent on the sandbar mainly through products they can yield as commodity from livestock. Their buffaloes prefer feeding upon *doob* or *Cynodon dactylon* and on *kans* or *Saccharum arundinaceum* in the sandbar. Goats prefer eating *doob*, *kans* and jhau grass (Tamarix species, or Salt cedar). The third section (farmers on the edge) raise chickens occasionally which are dependent on the sandbars for the various types of insects that they eat from the grass and also the grains that blooms over grasses on the sandbars.

Site 2

The farmers use to graze their animals such as cow, buffalo, and goat on the naturally occurring grasses in the channel deposits (Fig. 8). This may range from around 5 to 10 numbers. Grasses are also collected from these channel deposits to the town. The pastoralists who visit these lands only for four months from June to September lives in Shakurpur area of Delhi. Camels also grazed these lands and are used in town for camel ride. The grasses are collected by people living at a distance of around 7 km and are sold to the local market.

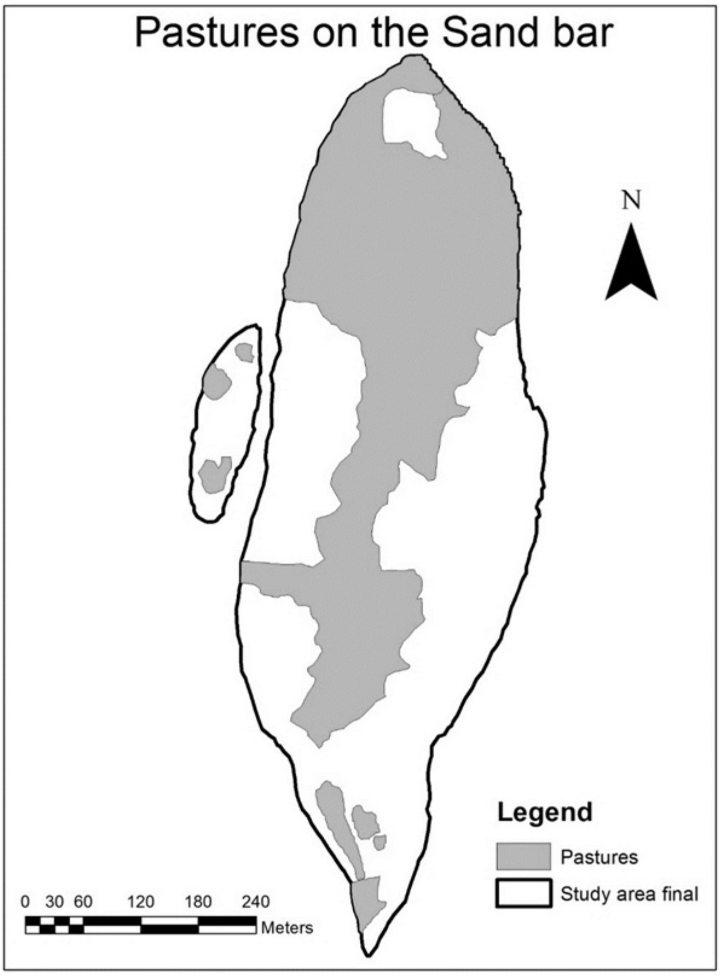

Fig.8. Pasturage observed in the study area (Site 2)

The pastures on the sandbars are being used by the two farmers who use the pasturage as fodder for their cattle, the salt cedar seller who cuts the salt cedar (*Jhau)* grass and sells it in the market to the bouquet shops, pastoralists who visit the island for 4 months (June-September) with their cattle and use the pasturage as fodder for them, and a family that also visits the island and gathers the *Saccharum spontaneum* (*kans)* grass to stall feed their cattle. Other vegetation growing naturally includes *Saccharum bengalense*, *Cynodon dactylon*, *Saccharum arundinaceum*, and *Tamarix* or *Salt cedar*. The figure (Fig. 9) below shows the amount of grass and other natural vegetation used by these different stakeholders.

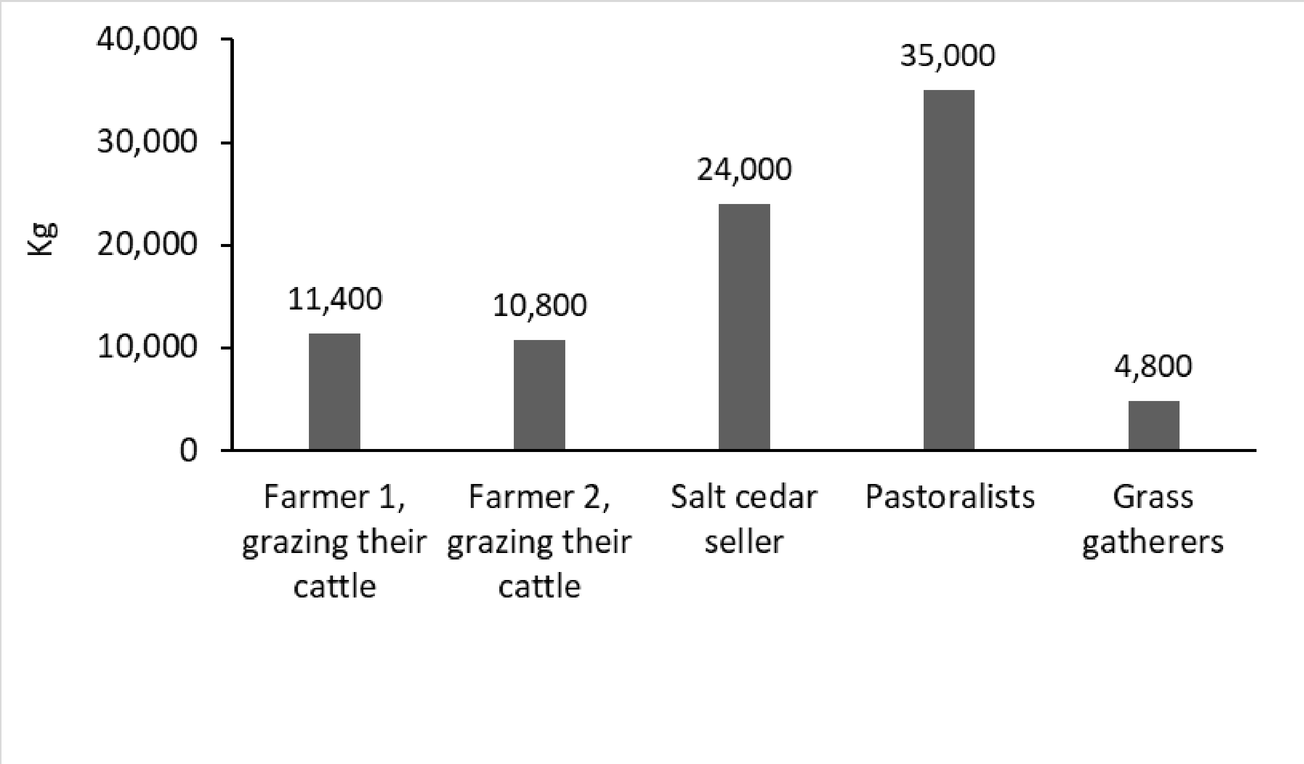

Fig.9. Stakeholders of naturally growing vegetation and annual collection/usage

Farmer 1 uses 11,400 kg of grass to feed the livestock, including buffaloes, goats, and hens. Farmer 2 uses 10,800 kg of grass for feeding his only cattle, Ox. The other important user of the sandbar's vegetation - salt cedar (*Jhau*) - is the salt cedar seller, who collects around 24,000 kg annually. Pastoralists, although they use the sandbar for 4 months, consume the maximum amount of grass for feeding their cattle. 45-50 cattle visit the island and graze for 7-8 hours, consuming around 35,000 kg of grass. The important point to note here is that no agricultural activity goes on in the sandbar during these 4 months. Another user of the pastures is the grass gatherers' family, which collects around 4,800 kg of *kans* (*Saccharum spontaneum*) from the sandbar. Pastoralists use the maximum proportion of grass on the sandbar. The reason for this is that a huge number of cattle, elephants, and camels graze the grass for 7-8 hours on a daily basis for 4 months. The salt cedar seller is the next in the priority list who uses the grass for selling in the flower market. The reason for this is that they cut the grass for the whole year except in the days of flood, but in the weeding season, they even visit the island twice in a day. There is a very little difference between the uses of pastures in the case of the two farmers, but then also, Farmer 1 uses the pastures more. Although Farmer 2 has only an ox who feeds on the grass, the ox grazes much more than the buffaloes. As grass gatherers visit the island for only 4 months and collect a small amount of grass, their dependency on the sandbar is low.

Other sandbar dependence and agroecosystem inputs and outputs

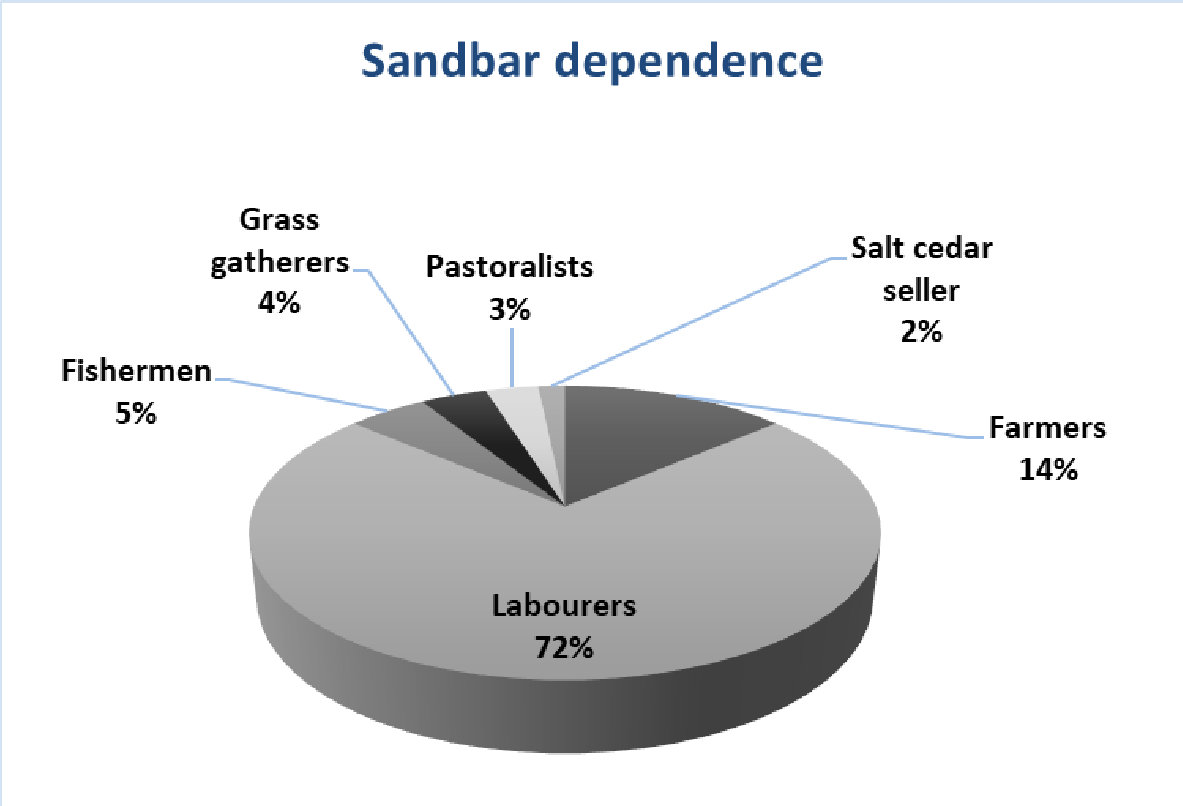

Fig.10. Population dependence on sandbar

The total population dependent (Fig. 10) on the sandbar for various activities is 124, out of which 90 are labourers who are engaged in the agricultural fields of the farmers. These labourers are dependent on the island for 8 months, after which they migrate to their hometown in Bihar. Farmers who have agricultural fields on the sandbar, including their family members, are 17 in number. Fishermen are 6 out of the total, pastoralists are 4 in number, and grass gatherers are 5 in number (a complete family) who visit the sandbar for 4 months when there is no agricultural activity going on. Salt cedar sellers who are dependent on the sandbar for the whole year (except in days of flood) are 2 out of the total.

Fig. 11. Agroecosystem inputs and outputs at site 1

Just like the cattle grazers, people with their camels and elephants visit the study area and leave them for grazing there for six to eight hours during June to September. The fishermen who visit the island frequently have licenses which are issued to them by the government itself. These fishermen look for a stretch of river in which they can easily spread their fishing nets. The study of the area revealed that 6 people come on alternate days to the island to catch the fish. These people come from Mandawali and sell the fish in the Ghazipur *mandi*. The species of fish which they trap from the island is

Catfish (locally known as Magur fish), whose price depends on the size and weight of the fish. For a normal 2 kg fish, they get 120-140 rupees from the *mandi*. The income of fishermen fluctuates per month as it depends on the availability of fishes. A rough estimate suggests 90 kg/month/per person of fish catch.

Among inputs (Table 3a, 3b) (Fig. 11), the seeds are brought by both the farmers from Laxmi Nagar (4 km from the study area). The price varies depending on the type of seeds. The fertilizers are brought by them from Laxmi Nagar and Baraf Khana (near Old Delhi railway station, 12 km away from the study area). They use 10-12 bottles of fertilizer for one cropping season. Urea is not used at all in the agricultural fields. Pesticides used in the field are Profex, Nagraj, Blotinax, Atabron in different quantities. The farmers used to spray the weedicide in the farmland. The weedicides are first mixed with water before spraying. They need to spray one bottle of it (250ml) for a month. Fertilizers are being sprayed in a good quantity in the field. It is observed that an amount of 5 lakhs rupees was spent for labour, seeds, and fertilizers in total. 50,000 rupees were invested in the seeds of all crops. In addition to this, 10-12 bottles of fertilizers are used in the fields of farmer 1. One bottle of fertilizer, weighing one, costs 650 rupees. Moreover, the labourers were also paid on a daily basis for 6 months (3 months during cultivation of the crops and 3 months for harvesting the crop). Fertilizers are primarily applied during the initial days and in times of rain. The fertilizers used are Atabron (250 ml, 150 Rs), Blotinax (100ml, 62 Rs), Profex super (1 litre, 650 Rs), Nagraj (300 Rs/litre) (Table 3c).

Table 3a. Input of seeds in terms of use and cost at site 1

Crop type	Farmer 1			Farmer 2			Farmer 3		
	Area (in *bigha*)	Seed sown (g)	Cost (Rs)	Area (in *bigha*)	Seed sown (g)	Cost (Rs)	Area (in *bigha*)	Seed sown (g)	Cost (Rs)
Pumpkin	Spaces in between	250	500	Spaces in between	250	500	Spaces in between	250	500
Ridged Gourd	2	750	3375	2	750	3375	2	750	3375
Bitter Gourd	3	1025	6150	2	750	4500	3	1025	6150
Bottle gourd	2	300	1200	2	300	1200	4.5	675	2700

Table 3b. Input of seeds in terms of use and cost at site 2

Crop type	Farmer 1			Farmer 2		
	Area sown (in *bigha*)	Seed sown (g)	Cost of seed (Rs)	Area sown (in *bigha*)	Seed sown (g)	Cost of seed (Rs)
Tomato	15	375	850	40	1000	2000
Pumpkin	3	1500	3000	4	2000	4000
Ridged Gourd	2	750	3750	2	750	3750
Bitter Gourd	1	375	2250	2	750	4500
Bottle gourd	2	300	1200	2	300	1200

Table 3c. Annual Input of pesticides in terms of use and cost at site 2

Fertilizer type	Farmer 1		Farmer 2	
	Quantity used (liters)	Cost (Rs)	Quantity used (liters)	Cost (Rs)
Profex	12	7800	20	13000
Nagraj	10	3000	14	4500
Blotinax	550 ml	400	750 ml	500
Atabron	3	2000	4	2500
		13200		20000

The Table 3d below shows the agroecosystem output as monthly crop production during the harvesting season starting from the March end till mid-June at site 1.

Table 3d. Agricultural production at site 1

Crop type	Farmer 1	Farmer 2	Farmer 3
	Monthly production (kg)	Monthly production (kg)	Monthly production (kg)
Pumpkin	300	300	300
Ridged Gourd	5000	5000	5000
Bitter Gourd	2800	1875	2800
Bottle gourd	1875	1875	4220

At site 2, both the families of farmers grow all the crops listed (fig. 12) (Table 3e). The family of Farmer 1 owns a total land area of 25-30 bigha, on the sandbar of which 20-22 bigha was cultivated in the study. Farmer 2 has 80-85 bigha of land area, including the other small sandbar, from which only 50 bigha of land was cultivated during the study year. The measurement of the land is done with footsteps. Farmers consider 20 footsteps = 1 Bigha. An important point to note here is that the farmers pay the fixed amount of money to the landowner irrespective of how much area they cultivate. As observed, both farmers have given a maximum area (more than half of the area) to the crop of tomato.

Table 3e. Agricultural production at site 2

Crop type	Farmer 1		Farmer 2	
	Area sown (in *bigha*)	Monthly production (kg)	Area sown (in *bigha*)	Monthly production (kg)
Tomato	15	15,000	40	40,000
Pumpkin	3	5,000	4	7,000
Ridged Gourd	2	2,000	2	2,000
Bitter Gourd	1	2,000	2	4,000
Bottle gourd	2	2,000	2	2,000

Fig.12. Agroecosystem inputs and outputs at site 2

Discussion and Conclusion

Agriculture is being practiced inside the urban areas of Delhi and its outskirts, and it plays a significant role in contributing towards the urban economy. Agroecosystems in river sandbars establish various linkages in local markets and fulfil local needs through agricultural output. Dynamic channel deposits in both the study areas are located amidst the urban landscape of Delhi and contribute towards the city's economy. A great part of its share is sold by farmers in the nearby Azadpur *mandi* or wholesale market, from where it is bought by different local retailers, which in turn sell their produce to various parts of Delhi and the NCR region. Also, the farmers themselves sell their vegetables to the residents of the neighbouring areas. Krishnamurthy [23] and Chowdhury [24] have elucidated how Bangladesh is relying upon sandbar cropping, growing pumpkin and squash as a means to achieve multiple goals, in large quantities on sandbars. Pimental [25] has discussed agroecosystems and how the resources derived from them, when used as input, could bring efficient results and therefore output in the crop production system. The author has argued that the energy input, in the case of agroecosystems, has evolved and become very demanding over time. The inputs and outputs in the present study include the use of fuelwood, fertilizers, pesticides, tractors, use of livestock/animal energy, labor/manpower on the farms, and other modern intensive agricultural management tools to carry out farming. The paper by Rahman and Reza [26] has emphasized the cultivation of the "palej" crop on the charlands (sandbars), specifically pumpkin, similar to the present study area. The pumpkin cultivation was practised on the charlands formed by the Brahmaputra River, which was earlier considered barren. The crop of pumpkin is grown on these lands as the crop is more adapted and requires low water for irrigation. A similar technique of digging furrows in the ground to grow '*palej*' is observed in the present study where crops can pull the groundwater on their own.

Randhawa [27] mentions that one of the methods to sell the crops in a small town is through brokers or *dalals* who help the farmers to dispose of their produce to the wholesalers known as *Arhatiyas*. Ashraf et al. [28] explains that the lease system on the charlands is very complex. These lands belong to the state legally, but in reality, they are owned by the powerful elite who act as feudal lords to the people living on the sandbars. The average farmer is so poor and indebted that he sells his produce to *Arhatiyas* to clear his previous debts and therefore plays an important role. Moreover, the farmers do not have warehousing facilities to store the produce longer, therefore they bring the produce to the mandi on the same day and sell it to the *Arhatiyas*. He works both as a moneylender cum trader[29]. In the present study, it is observed that farmers do not get the actual price of their produce. The rate of the vegetables depends on the market. If they harvest the vegetable on the day when the price of that vegetable is low in the market, they have to anyway sell it to the *arhatiya*. If they would keep the vegetable for long, the vegetable may get rotten. The *arhatiya* is not fixed. Once the money taken from *arhatiyas* is paid back to them by the farmers, the farmers can even switch to other *arhatiyas*.

Lahiri [3] explains that people who live adjacent to the newly emerged sandbar, or people who are richer or have better political affiliations mobilise higher sentries and gain control over these islands particularly of cropping and harvesting on these lands. This further leads to disputes over the ownership of lands. In the present study it is observed that when the sandbar has emerged close to the land of the claimant who being powerful and rich, have taken control of the sandbar and has given the land on lease to the two farmers for practising agriculture on it. In Bangladesh however, it is observed [30] that these charlands belong to government but illegally taken over by the people living close to these. These unusable lands once approached/accessed by poor people can be put to use by providing them with livelihood and food security. Hammelman et al. [31] in a study in Argentina mentioned about the power dynamics embedded in sustaining agroecological projects in urban areas. In the present study also, we can observe power dynamics in a very different setting.

It is important to bring urban agriculture within the design of cities to address issues related to environment and economics [32]. As urban farming provides beneficial ecological, social, and educational services, it needs similar importance like schools, museums, parks, modern infrastructure in the city planning [33]. Studies indicate that between 76 and 90% of vegetables are provided by urban agriculture in Dar es Salaam, Tanzania, Shanghai and Beijing. Dakar produces around 60% of Senegal's vegetables. In Vietnam, 80% of fresh vegetables comes from Urban areas [17]. Overall, global estimates of available space for urban agriculture ranges from 1-7 million hectares or 1.4%–11% of the urban area [34]. Urban food production has increased around 30% between early 1990s and mid-2000[20]. For a proper food planning in urban areas, Deh-Tor [35] forwards two ideas; first is to stop separating agriculture from urbanisation conceptually, which he suggests is driven by capitalistic mindset and is not real. Second, the land for food production, and its quality, in urban areas needs to be the one of central point of focus in urban planning. This would mean proactive policies for land protection in urban areas.

Acknowledgements

The author would like to acknowledge Ms. Yashika Gupta, Ms. Shipra Maheshwari, and respondents of the study sites for participating in the study.

References

1. ^*T.K. Das, S.K. Haldar, I.D. Gupta, S. Sen, River Bank Erosion Induced Human Displacement and Its Consequences, Living Rev. Landscape Res., 8 (3), (2014). http://dx.doi.org/10.12942/lrlr-2014-3*
2. ^*T.J. Coulthard, Effects of Vegetation on Braided Stream Pattern and Dynamics, Water Resources Research, 41: (2005) W04003, [doi] 10.1029/2004WR003201.*
3. a, b, c*K. Lahiri-Dutt, Chars: Islands that float within rivers, Shima: The International Journal of Research into Island Cultures 8 (2), 2014, 22-38*
4. ^*B. Gopal, D.K. Banerjee, T.R. Rao, Enhancing water flow in River Yamuna at Delhi Research and Action Plan, for National River Conservation Directorate, MoEF New Delhi, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, 2002, pp: 236*
5. ^*National Dalit Watch, The uncertainties of life, living through waters of dejection, National Campaign on Dalit Human Rights, New Delhi, www.ncdhr.org.in, 2010*
6. ^*A. Baviskar, What the Eye Does Not See: The Yamuna in the Imagination of Delhi, Economic & Political Weekly, Vol-xlvi, No. 50 (2011)*
7. ^*C.R. Babu, A.K. Gosain, B. Gopal, Restoration and conservation of River Yamuna, Final Report Submitted to National Green Tribunal. (Tribunal's order dated 24 September 2013), 2013, Expert Committee constituted by the Ministry of Environment and Forests, New Delhi (Order No. K-1301/2/2013-NRCD Dated 13 September, 2013).*
8. ^*S. Maheshwari, The geographical and socio-economic dynamics of life in the Yamuna sandbars in Delhi, MA Internship report, School of Human ecology, Ambedkar University Delhi, 2016*

9. ^*Y. Gupta, Socio – economic impacts of unstable channel deposits in River Yamuna at Delhi using GIS, MA Internship report, School of Human ecology, Ambedkar University Delhi, 2016*
10. ^*M. Prashnani, A. Qadir, J. Goswami, P.L.N. Raju, Spatio-temporal study of Brahmaputra River Islands (CHARS) for agriculture expansion in Assam, India. In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 42(3/W6), 2019, pp. 429–433. https://doi.org/10.5194/isprs-archives-XLII-3-W6-429-2019.*
11. ^*G. Talukdar, A.K. Sarma, R.K. Bhattachajya, 2021. Sediment analysis and modelling based approach for optimal allocation of riverine sandbar for socio economic benefits, Ecological Engineering 173, 106415, https://doi.org/10.1016/j.ecoleng.2021.106415*
12. ^*R. Fricano, C. Davis, How well is urban agriculture growing in the Southern United States? Trends and issues from the perspective of urban planners regulating urban agriculture. J. Agric. Food Syst. Community Dev., 9, 31–53 (2020)*
13. ^*B.B. Lin, S.M. Philpott, S. Jha, The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. Basic Appl. Ecol. 16, 189 (2015)*
14. ^*S. Jha, M. Egerer, P. Bichier, H. Cohen, H. Liere, B. Lin, A. Lucatero, S.M. Philpott, Multiple ecosystem service synergies and landscape mediation of biodiversity within urban agroecosystems, Ecology Letters, 26(3) (2023) 369-383. https://doi.org/10.1111/ele.14146*
15. a, b*T. Thiesen, M.G. Bhat, H. Liu, R. Rovira, 2022. An Ecosystem Service Approach to Assessing Agro-Ecosystems in Urban Landscapes. Land, 11, 469. https://doi.org/10.3390/land11040469*
16. ^*E. Holt-Gimenez, A Foodie's Guide to Capitalism: Understanding the Political Economy of What We Eat. Monthly Review Books, 2017, New York*
17. a, b*M.A. Altieri, C. I. Nicholls, Urban Agroecology: designing biodiverse, productive and resilient city farms, Agro Sur 46(2) (2018) 49-60, DOI:10.4206/agrosur.2018.v46n2-07*
18. ^*E. Greenberg-Bell, C. Baglien, D. T. Schwei, K. Havey, Minneapolis Urban Agriculture Survey 2019. Minneapolis, MN: Homegrown Minneapolis. (2019)*
19. ^*J.A. Nicklay, K.V. Cadieux, M.A. Rogers, N.A. Jelinski, K. LaBine, G.E. Small, Facilitating Spaces of Urban Agroecology: A Learning Framework for Community-University Partnerships. Frontiers in sustainable food systems 4:143 (2020). doi: 10.3389/fsufs.2020.00143*
20. a, b*F. Martellozzo, J.L. Landry, D. Plouffe, V. Seufert, P. Rowhani, N. Ramankutty, Urban agriculture: A global analysis of the space constraint to meet urban vegetable demand. Environmental Research Letters 9(6), 1-8 (2014) https://doi.org/10.1088/1748-9326/9/6/064025*
21. ^*M.G. Badami, N. Ramankutty, Urban agriculture and food security: A critique based on an assessment of urban land constraints. Global Food Security 4, 8-15 (2015) https://doi.org/10.1016/j.gfs.2014.10.003*
22. ^*H. De Zeeuw, R. van Veenhuizen, M. Dubbeling, The role of urban agriculture in building resilient cities in developing countries. The Journal of Agricultural Science 149(S1), 153-163 (2011) https://doi.org/10.1017/S0021859610001279*
23. ^*R. Krishnamurthy, Sandbar cropping in Bangladesh, https://permaculturenews.org/2014/04/25/sandbar-cropping-bangladesh/, 2014*
24. ^*N.I. Chowdhury, Sandbar cropping in Bangladesh, an innovative technology solution for millions,*

http://www.aidforum.org/food-security/sandbar-cropping-in-bangladesh-an-innovative-technology-solution-for-millio, 2016.

25. ^*D. Pimental, Energy flows in agricultural and natural ecosystems, Options, CIHEAM – Options Mediterraneennes, 1983, 125-136*
26. ^*K. Rahman, I. Reza, Accessing and Retaining access to the sandbars by the extreme poor: Experiences from the practical action project, Extreme poverty research group (EPRG), Chars livelihood programme, 2012, SHIREE – Working paper 9, Bangladesh.*
27. ^*K.S. Randhawa, T. Remigius, Market around us, In Sahi, M. N. & Kaur, M. (Eds.), 'India and the modern world' (36-39). 2015, New Delhi: Evergreen Publications.*
28. ^*E. Ashraf, M.B. Hossin, S. Ito, A. Shonchoy,. Impacts of periodic floods in River Islands of North-West Bangladesh: Background and Research Questions, Interim Report, Institute of Developing economies, Japan External Trade Organisation, 2013.*
29. ^*J. Prasad, A. Prasad, Indian Agricultural Marketing: Emerging Trends & Perspectives, Mittal Publications, 1995, pp 268, ISBN 8170996155*
30. ^*S. Mandal, M. Kleinke, N. Chowdhury, N. Bepary, Accessing newly accreted land by the poor farmers: Innovations towards food security in Bangladesh. TROPENTAG 2015, Management of land use systems for enhanced food security – conflicts, controversy and resolutions September 16 – 18, 2015, Humboldt-Universität zu Berlin, Germany.*
31. ^*C. Hammelman, E. Shoffner, M. Cruzat, S. Lee, Assembling agroecological socio-natures: a political ecology analysis of urban and peri-urban agriculture in Rosario, Argentina, Agriculture and Human Values 39:371–383 (2022), https://doi.org/10.1007/s10460-021-10253-7*
32. ^*L.J. Pearson, Sustainable urban agriculture: Stocktake and opportunities. Int. J. Agric. Sustain. 8, 7–19 (2010)*
33. ^*A. Siegner, Urban Agroecology: An essential resource for times of crisis and beyond, Policy Brief, The Berkeley Food Institute (BFI), 2021, University of California, Berkeley*
34. ^*N. Clinton, M. Stuhlmacher, A. Miles, N. U. Aragon, M. Wagner, M. Georgescu, C. Herwig, P. Gong, A Global Geospatial Ecosystem Services Estimate of Urban. Agriculture. Earth's Future 6(1), 40-60 (2018) https://doi.org/10.1002/2017EF000536*
35. ^*C.M. Deh-Tor, Food as an urban question, and the foundations of a reproductive, agroecological, urbanism, in TORNAGHI C., DEHAENE M. (eds.), Resourcing an agroecological urbanism. Political, transformational and territorial dimensions, London: Routledge; 2021, Ch. 1, pp. 12-33*