Land Use Classification Bangladesh

Combining and downscaling existing databases

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1 Wageningen Environmental Research
2 FAO, Bangladesh
3 Bangabandhu Sheikh Mujibur Rahman Agricultural University
4 Center for Environmental and Geographic Information Services (CEGIS)
5 Wageningen Economic Research
6 Wageningen Centre for Development Innovation

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Approved for publication:
Sander Janssen, team leader of Earth Observation and Environmental Informatics

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Bangladesh is a south Asian country with lush greenery and many natural waterways. Bangladesh consists mostly out of fertile flat lands. Due to urbanisation, agricultural expansion and intensification as result of population and economic growth the use of the natural land system is changing rapidly. Understanding current land cover and how the land is being used is elementary for land management and land use planning. In this study we developed a spatial land use classification database of Bangladesh based on existing land cover classifications, census data of agricultural yields, cropping areas, and supplemented with local knowledge.

Keywords: land cover, land use, census, model, downscaling, mappin

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name: dr. C.A. Mücher

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name: S. Janssen

date: 8 September 2022

Project background

Bangladesh's capital, Dhaka, is home to over 20 million people and faces many challenges to supply its citizens with fresh, nutritious and affordable food. One-fifth of Dhaka's population lives below the poverty line and have poor diets due to a lack of availability of and access to nutritious food. There is also a lack of availability and access to healthy food. As Dhaka's population and economy are expected to grow further in the future, these challenges will only increase.

In response to such challenges the Support for Modelling, Planning and Improving Dhaka's Food System (DFS) project aims to make Dhaka's food system more resilient and sustainable by supporting the Government of Bangladesh to gain understanding of the relations and trends within the food system and its dependency on the socio-economic and environmental system. This understanding is essential in planning for the future.

There are different elements that make up the food system value chain: food production, processing, storing, retailing, consuming and disposing. The majority of food consumed in Dhaka is produced within Bangladesh. This report explores the spatial elements of food production through the development of a map which is crucial in understanding transportation implications (e.g. time and prices) and future-proofing of agricultural production influenced by urbanization (e.g. loss of agricultural land) and climate change (e.g. salinization).

1 Introduction

Bangladesh is a south Asian country with lush greenery and many natural waterways due to its delta. Bangladesh consists mostly out of fertile flat lands with just north of its borders the Himalayas, and south the bay of Bengal. There are three big rivers flowing through the country: the Ganges, Brahmaputra and Meghna. The northeast and southwest are home to evergreen hill ranges. Due to its low lying flatness it has a vulnerable coastal area and is susceptible to large scale flooding. With a population of about 160 million on almost 150 thousand square kilometers it is one of the most populated countries in the world, and its growing fast.

Due to urbanisation, agricultural expansion and intensification as result of population and economic growth the use of the natural land system is changing rapidly. The land is further under pressure by climate change effects such as sea level rise, salinization, floods and droughts impacting the livelihoods of the people. These changes highly affect the use of the land for agricultural purposes and thereby the food availability and food security.

The interaction of the natural ecosystems with human activities is reflected in the land cover. Understanding current land cover and how the land is being used, especially with regard to the aforementioned challenges, is elementary for land management and land use planning. Measuring current conditions is achieved through land cover mapping. Satellite images are often used as basis for land cover mapping as it allows to take a measured snapshot covering the entire study area at a single moment in time. Land cover mapping classifies the land in forest, urban, agricultural, bare soil and water areas. To understand the agricultural use of the land cover maps must be combined with other data sources.

In this study we developed a spatial land use classification database of Bangladesh based on existing land cover classifications, census data of agricultural yields, cropping areas, and enriched with local knowledge.

The content of the report is as follows, in Chapter 2 we discuss the materials used in the development of the land use map. Chapter 3 explains the land use classes and Chapter 4 shows the resulting land use map, including a quality assessment of the map.

2 Materials

2.1 Copernicus global land cover map

The European Copernicus service provides systematic global monitoring of the Earth's land surface via satellite imagery. This satellite imagery is freely under an open source license. Since 2015 the Copernicus service release yearly global land cover maps at 100 meter resolution. In addition to the discrete land cover map a set of cover fraction layers is available. These cover layers depict the percentual cover of land cover types per pixel (Buchhorn et al., 2020). See Figure 1 for the Copernicus discrete land cover map of Bangladesh.

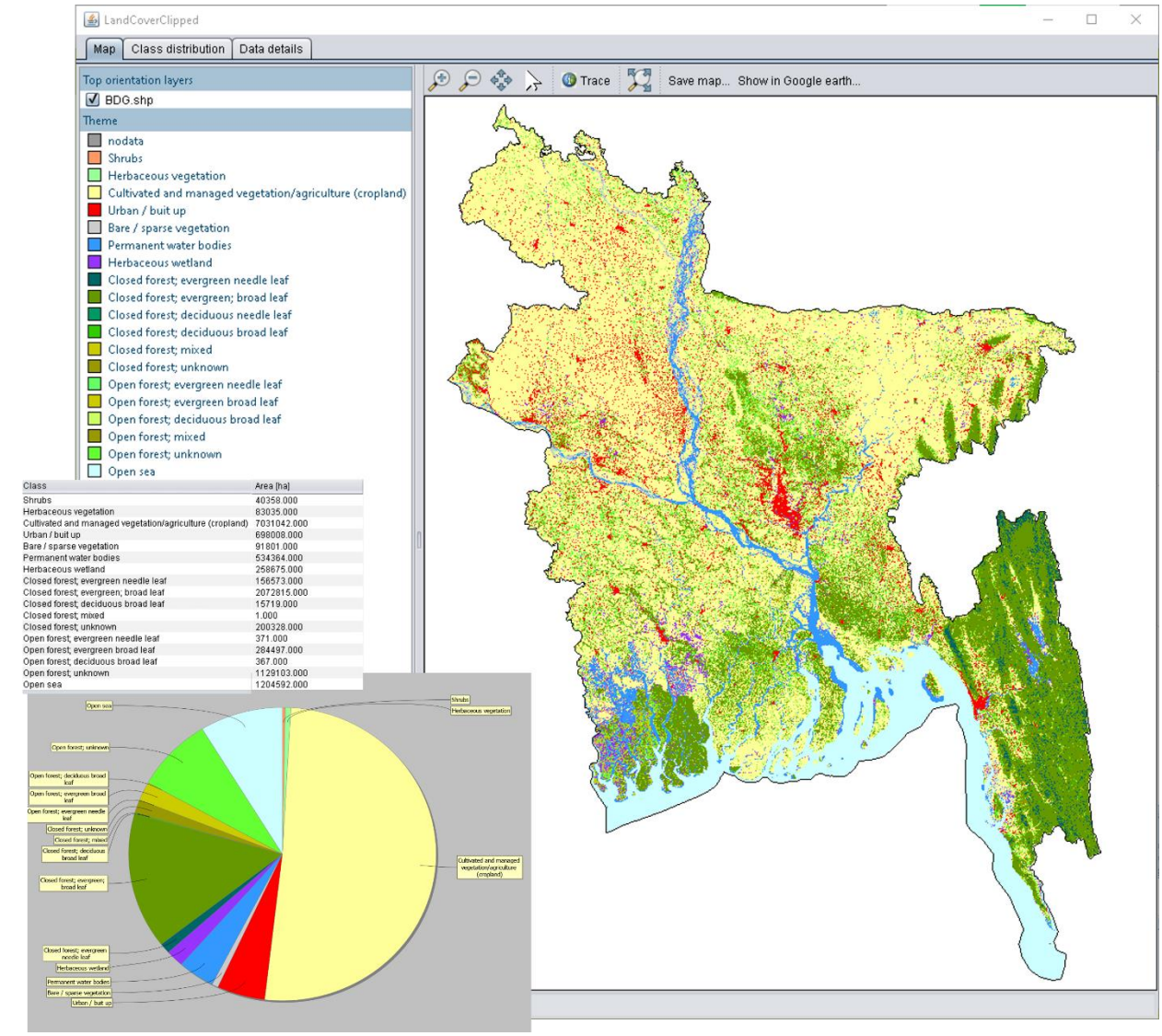

Figure 1 *Copernicus land cover map of Bangladesh.*

2.2 Crop distribution estimation from MAPSPAM

Census data on crop yields are periodically gathered by the Bangladesh Bureau of Statistics (BBS). The census data is gathered by administrative units. Each administrative unit holds a single value for the total yield of that area. In reality such an administrative unit covers agricultural lands, forest, water and urban areas. Crops are only grown on agricultural areas. Census data can be downscaled by allocating it to agricultural areas only.

MapSPAM datasets represents plausible estimates of crop distribution within disaggregated units created on principle of cross-entropy using the Spatial Production Allocation Model (SPAM). Besides to understanding production and land use patterns, dataset helps to identify where trends take place important for understanding why they take place (International Food Policy Research Institute, 2019).

In our study we aggregated 38 SPAM base classes into 6 categories (rice, pulses, vegetables spices & others, roots / tubers & perennials, maize system and wheat system).

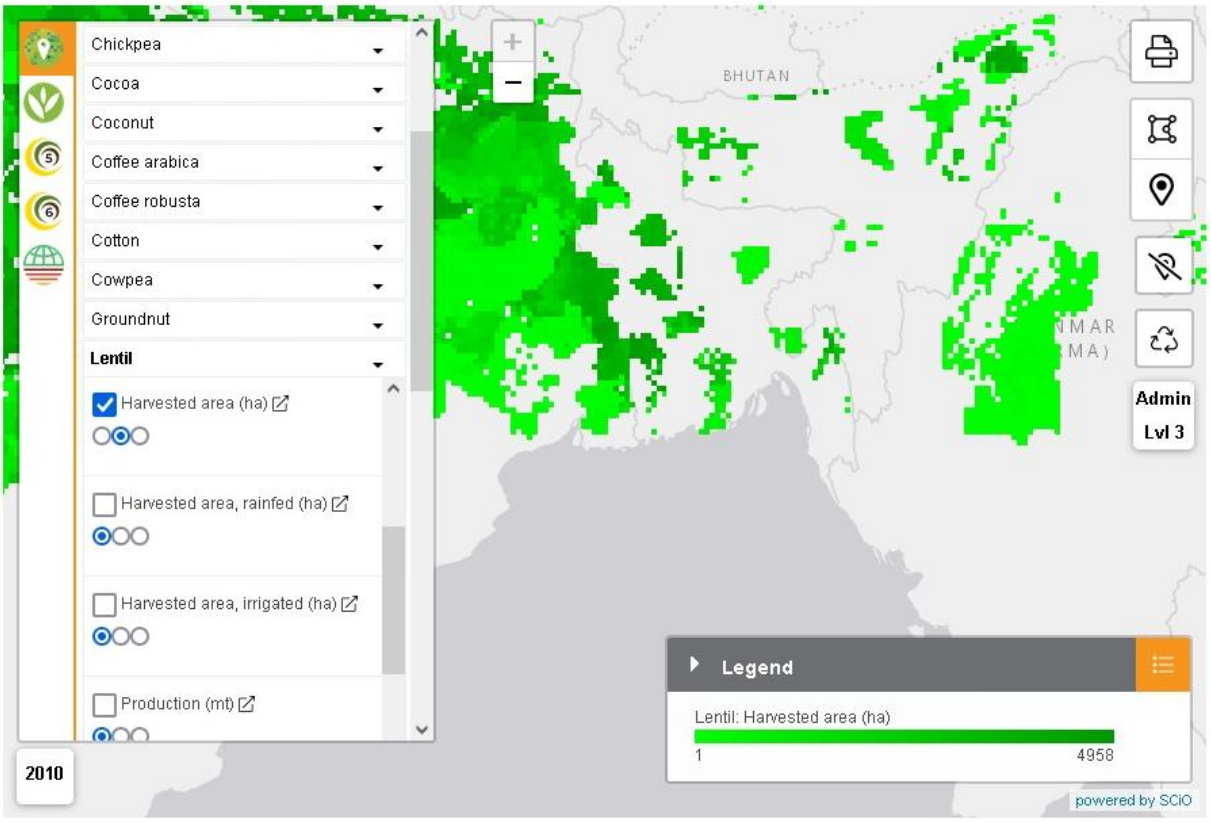

Figure 2 *Screenshot of MAPSPAM data download application. The displayed map shows the harvested area of lentils and is presented here as example for illustration purposes.*

2.3 Paddy rice from Sentinel 1

Rice is the staple food for Bangladesh. In recent years, paddy rice cultivated areas have become increasingly threatened by climate change (changing patterns of precipitation, flooding, droughts) and rapid urbanization and industrialization. This has resulted in utilizing the limited lands with the intensifying cropping cycles and increased uses of water resource to enhance the production. Singha et al. (2019) used Sentinel-1 SAR backscatter satellite imagery to create a 10x10 meter resolution paddy rice map for Bangladesh. See for the 100x100 meter aggregation of the paddy rice map of Bangladesh.

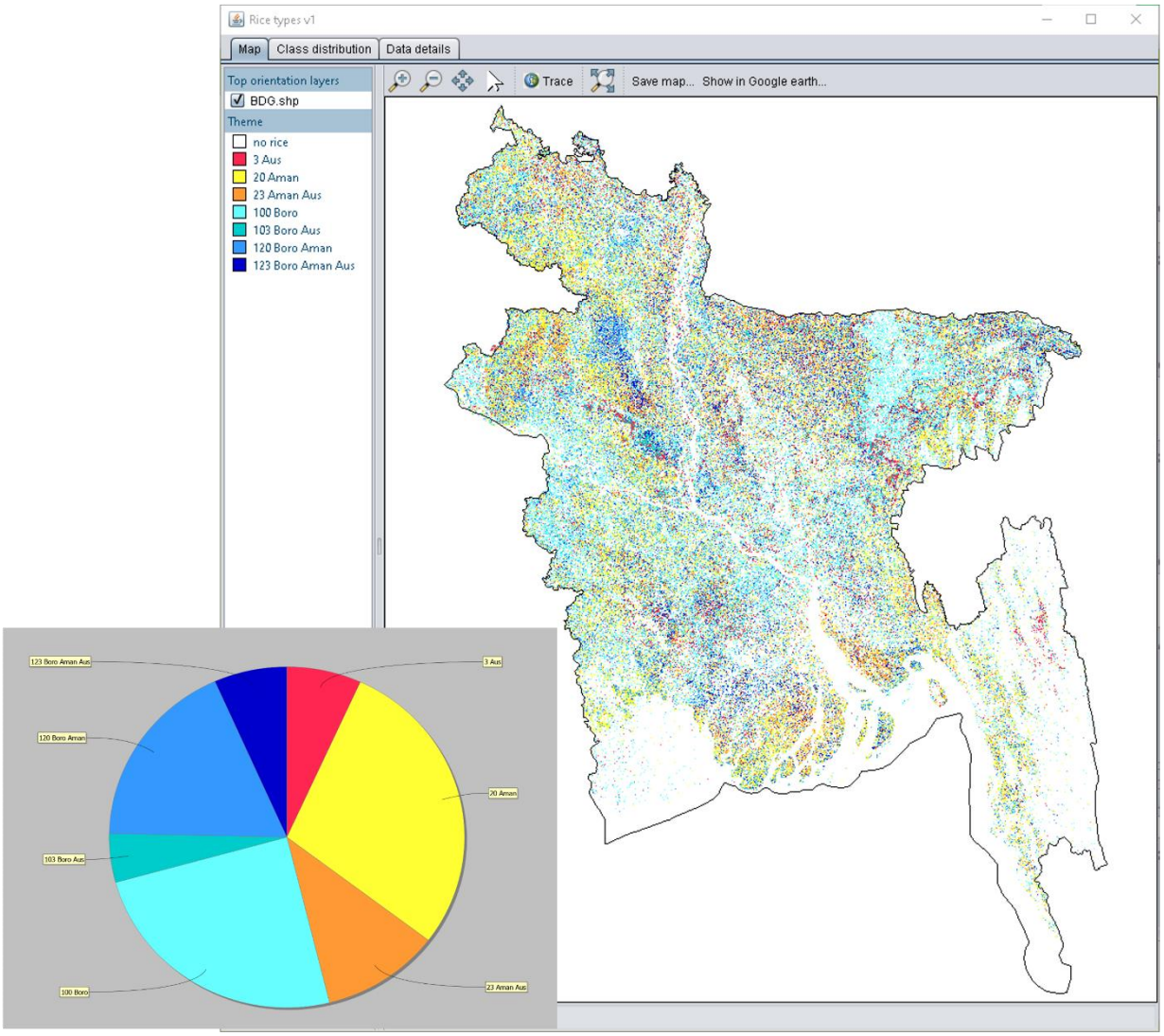

Figure 3 *Aggregation to 100x100 meter of the Sentinel-1 based Singha et al.(2019) paddy rice map.*

2.4 Urban night light as proxy for urban density

Remote sensing based land use data are a crucial data source for monitoring urbanization (Xi Li et al., 2019). Anthropogenic sources of light emissions are a good indicator for the magnitude and signature of human activity (Cheon & Kim, 2020). The combination of both data sources inform on the urban density (Roman et al., 2018).

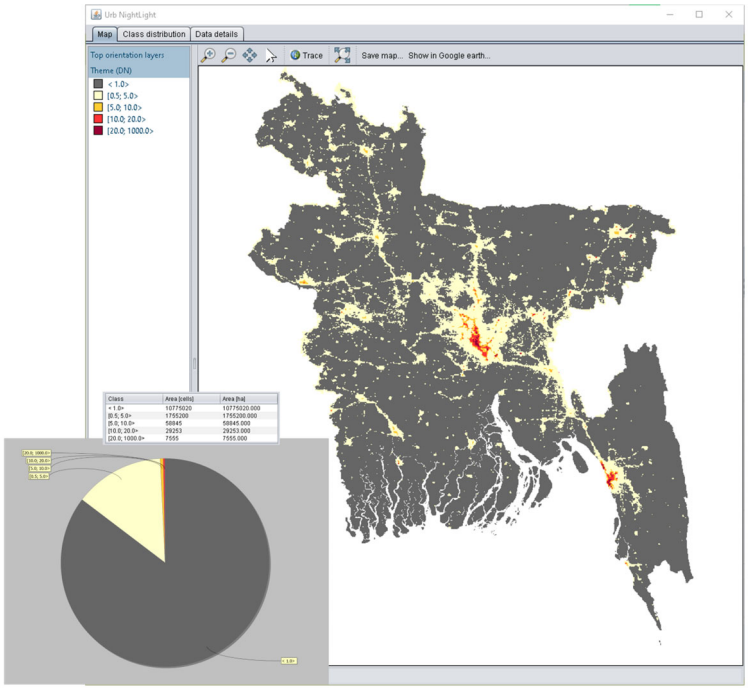

Figure 4 *Urban night light as proxy for urban density.*

2.5 Mangrove canopy height

Mangroves are forested wetlands that link terrestrial and marine ecosystems. Mangroves provide habitat to many marine species and play thereby a big role in food provisioning. Besides, mangroves protect the coast against storms and capture four times as much carbon as other terrestrial ecosystems. Simard et al. (2000) estimated mangrove canopy height based on remote sensing and field observations (Simard et al., 2000).

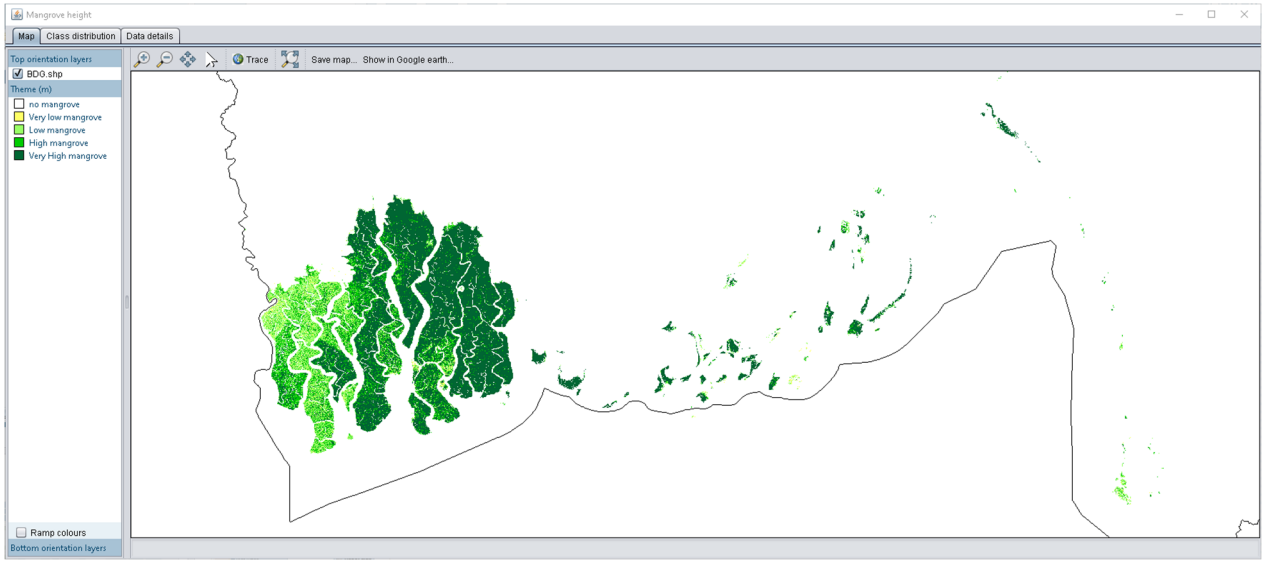

Figure 5 *Mangrove canopy height for Bangladesh.*

2.6 Administrative units from GeoDash

Bangladesh is divided into 8 divisions and 64 districts. For local government, the country is divided into Upazila, municipalities, city corporations and union councils (Figure 6).

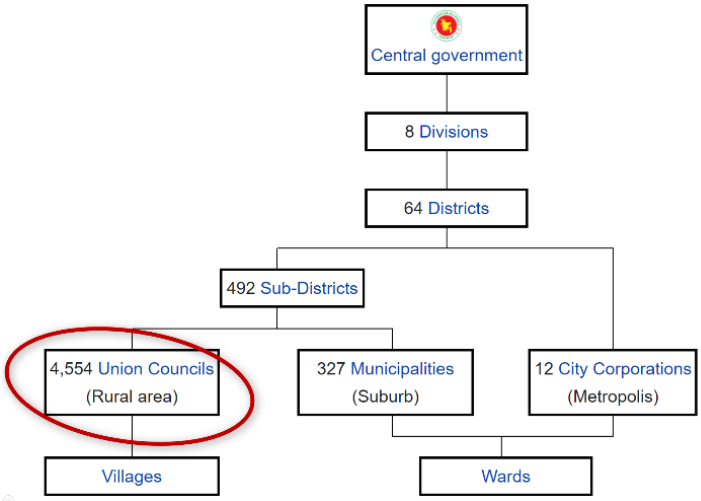

Figure 6 *Administrative divisions of Bangladesh.*

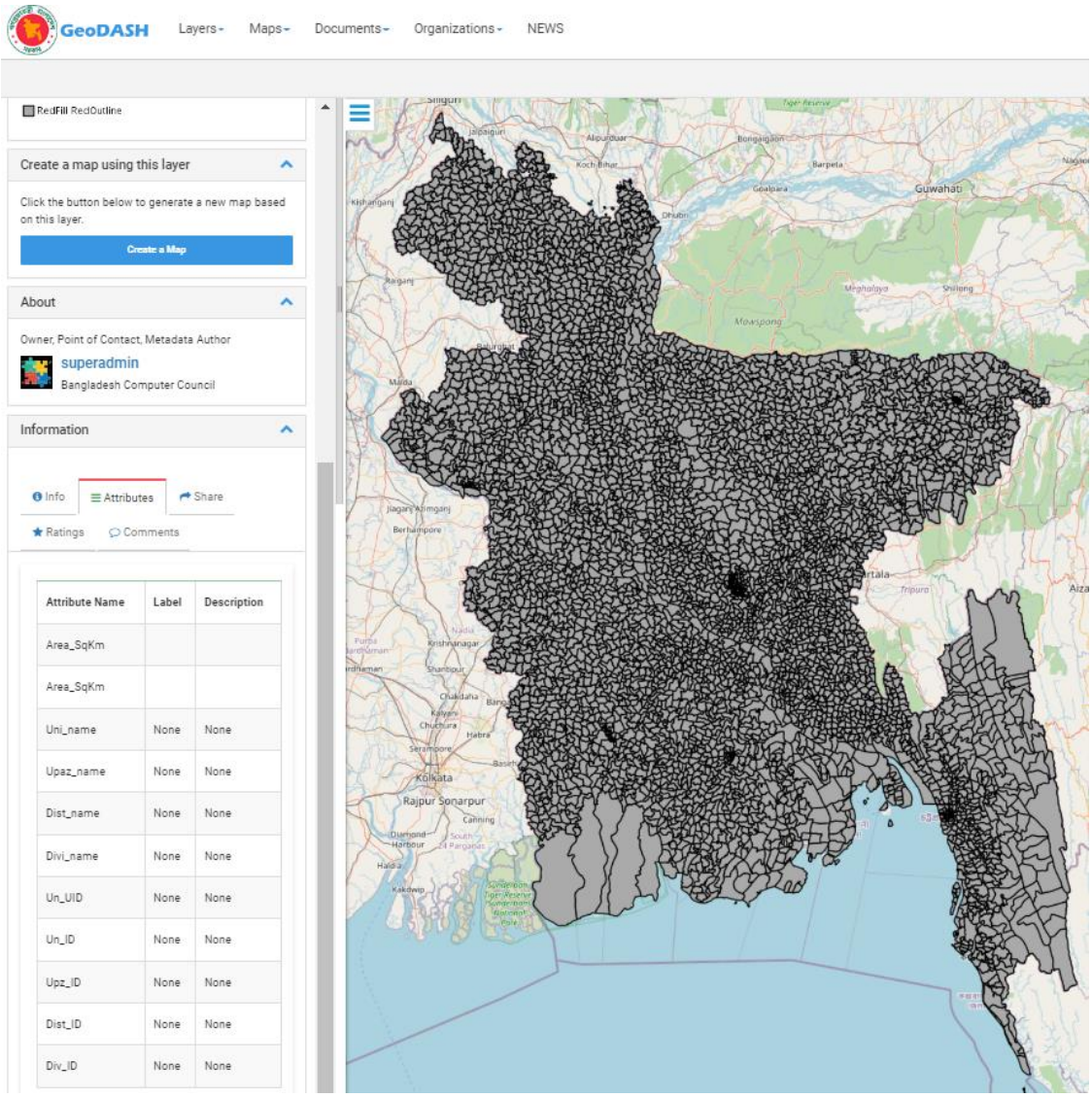

Figure 7 *Bangladesh administrative units.*

3 Land use classification

The land use classification of Bangladesh is in a first stage based on Remote Sensing, the Copernicus global landcover map at 100x100 meter resolution (Buchhorn et al., 2020). This classification does not distinguish between arable land uses. As especially these are arable classes are relevant for the food system of Dhaka, these have been further specified. Nasim et al. (2017) provide the distribution of 316 crops and cropping patterns in Bangladesh. After similar cropping patterns were grouped, a threshold of 2% was applied to keep larger cropping patterns only. This resulted in 7 major cropping systems:

- Rice + pulses
- Rice + vegetables
- Rice + fishponds
- Rice + roots & tubers
- Rice + maize
- Rice + wheat
- Vegetables

For allocating the cropping systems inside the arable land, various existing data sources were used. First, downscaled cropping area census data from MAPSPAM (International Food Policy Research Institute, 2019). 48 Cropping areas at 10x10 km resolution were, in combination with paddy rice at 10x10 meter resolution (Singha et al., 2019), merged towards the same 7 major cropping systems. This resulted in Cropping area maps at 10x10 km resolution. A differentiation of rice types was included to better match the cropping systems. Different rice types grow under quite different circumstances (e.g. irrigated, or flooded).

Secondly, cropping areas were summed and standardized to cropping suitability per administrative unit (Bangladesh Computer Council, 2019) to better fit data origin (census). Thirdly, allocate cropping systems to cells based on suitability and total land area per system. A system is assigned to the highest suitable areas. System that have narrow crop suitability ranges are allocated before less demanding crops. The 7 major cropping systems listed above are ordered accordingly.

In the final two steps urban nigh light (Roman et al., 2020) and canopy height (Simard et al., 2019) are used to distinguish between open and dense built-up area and mangroves.

LUID	LUNames	ha2020	Share2020	Nasim et al 2018	Singha et al 2019	FAOSTAT	LU Map2020
2000	Shrubs	28099	0.2%				
3000	Herbaceous vegetation	64834	0.5%				
4100	Rice Boro	1319223	9.6%	13.2%	24.6%		19.0%
4200	Rice Aman	569255	4.1%	6.5%			8.2%
4201	Rice Aman with Maize (maize, millet, sorhum, etc)	207805	1.5%	2.0%	28.5%	2.6%	3.0%
4202	Rice Aman with Wheat & Fibres (wheat, barley, jute etc)	694345	5.0%	9.3%		2.7%	10.0%
4300	Rice Aus	61402	0.4%	0.2%	6.8%		0.9%
4400	Rice Aman with Aus	287695	2.1%	2.4%			4.1%
4401	Rice Aman/Aus with Pulses (peas, lentils, etc)	621284	4.5%	9.3%	10.8%	2.8%	8.9%
4402	Rice Aman/Aus with Vegetables & Spices (lettuce, onions, mustard, sesame, etc)	816294	5.9%	11.8%			11.8%
4500	Rice Boro with Aman and/or Aus	1352160	9.8%	31.9%		3.7%	19.5%
4501	Rice Boro/Aman with Root-/Tubercrops(potatoes, etc)	332855	2.4%	4.5%	29.3%		4.8%
4502	Rice Boro/Aman with Fish	49902	0.4%	0.7%			0.7%
4600	Vegetables, Spices and other crops	629844	4.6%	8.3%		11.1%	9.1%
5100	Urban dense	29741	0.2%				
5200	Built-up	904715	6.6%				
6000	Bare / sparse vegetation	89202	0.6%				
8000	Permanent water bodies	532067	3.9%				
9000	Herbaceous wetland	206784	1.5%				
11000	Closed forest (including plantations, fruit trees, palm, etc)	2242953	16.3%				
12000	Open forest (including plantations, fruit trees etc)	1252995	9.1%				
13100	Mangroves dense	200630	1.5%				
13200	Mangroves open	104383	0.8%				
20000	Open sea	1203182	8.7%				

Figure 8 *land use classes and their relative areal coverage according to various sources.*

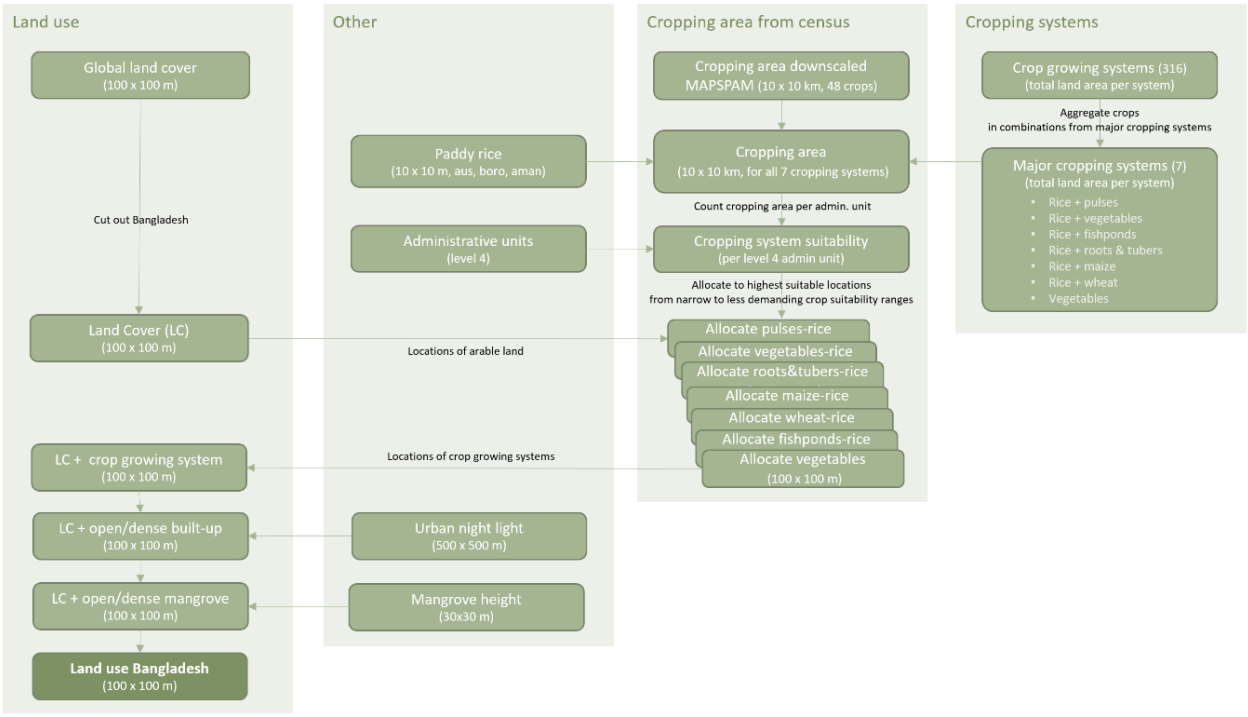

Figure 9 *Method for deriving the land use map.*

4 Results and quality assessment

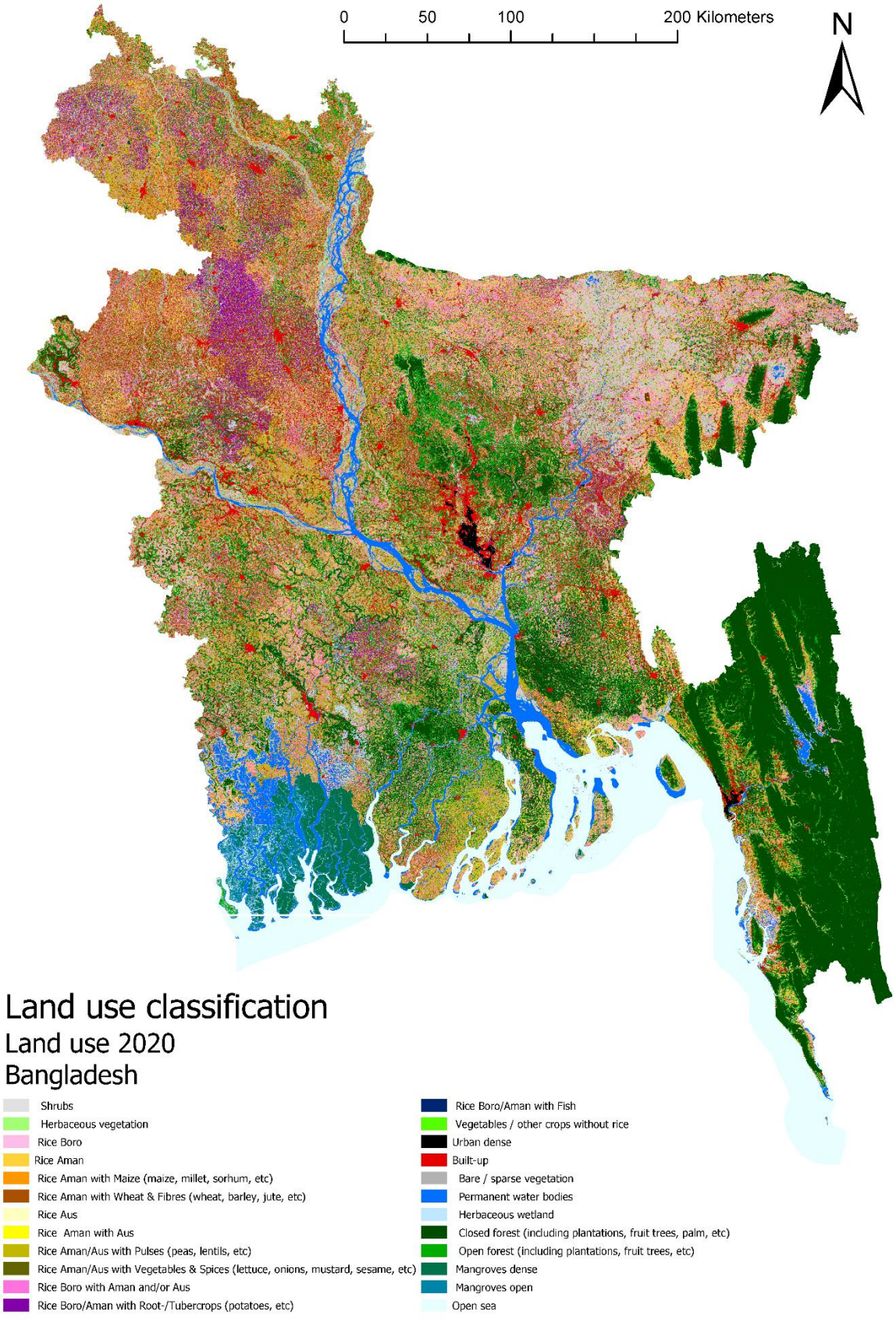

Figure 10 *Land use map of Bangladesh.*

A map of the resulting land use database is presented in Figure 10. The map contains 24 land-use classes on a 100x100 meter resolution for the year 2020. The class distribution is shown in Figure 11.

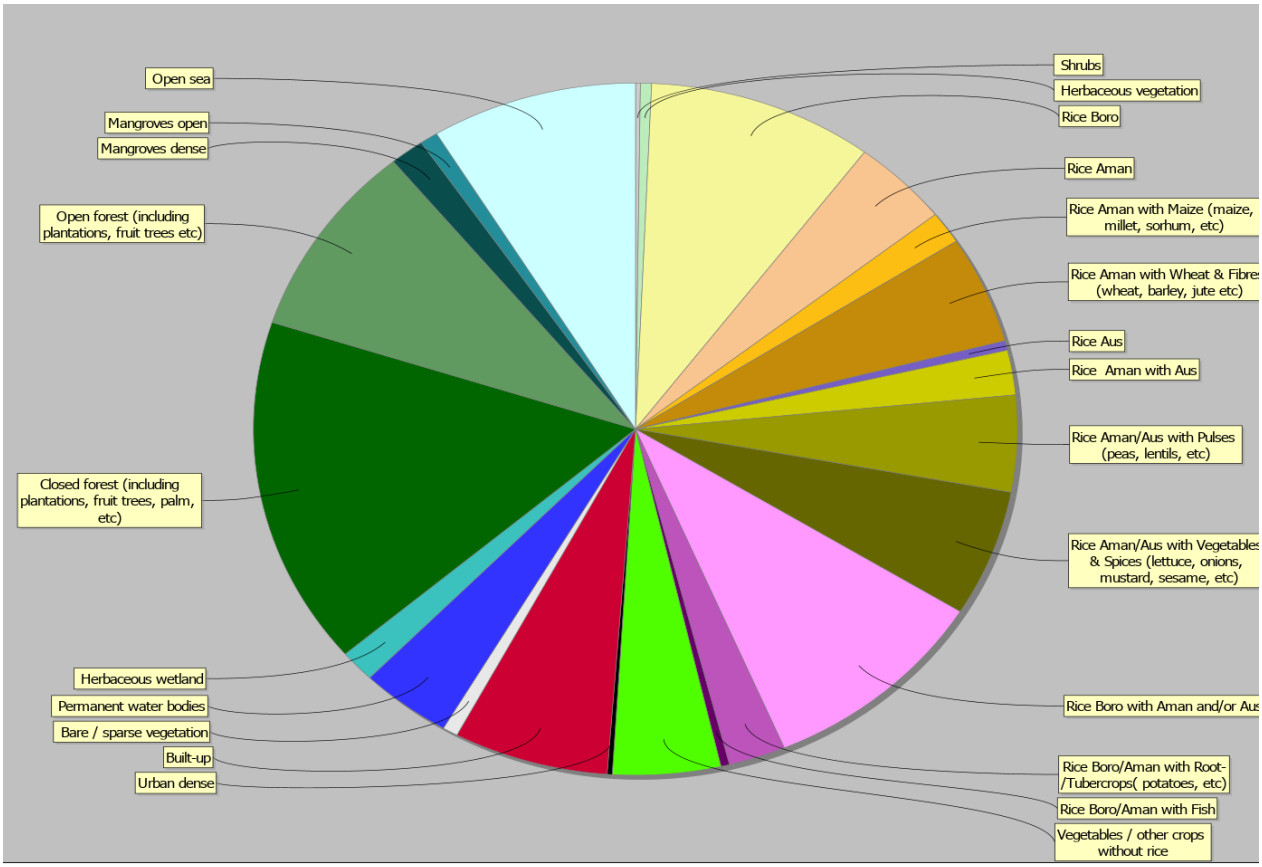

Figure 11 *Distribution of land use classes in Bangladesh map.*

The quality of any map is the product of spatial resolution, the assignment of classes to a location and the overall spatial pattern in relation to the map's purpose. There are many numerical methods available for such quality assessments (see for example Ukrainski, 2016). For this study no accuracy assessment has been made, instead a visual assessment by local experts and a statistical assessment were performed.

The visual assessment was performed by asking local experts to check the land use map and reflect whether the spatial patterns visible in the map were corresponding with their knowledge of the land use in Bangladesh. The local experts reported the following:

- In the Chittagong region forest is observed, which is uncommon.
- The map is representative of the current land use situation in Bangladesh and the observed spatial patterns are correct.
- The boro rice and potato cultivation hotspots in the northwest are accurate.
- The cities Dhaka, Khulna, Rajshahi and Sylhet are clearly visible on the map. In addition, the map illustrates the disappearance of rice cultivation around Dhaka, which had to make way for vegetable cultivation and industries. For agricultural cultivation, the map correctly shows boro rice and potato cultivation in the northwest, mango trees in Rajshahi, fish ponds in the southwest and boro rice cultivation between Sunamganj and Sylhet (northeast).
- In the Sundarban nature area (southwest Bangladesh) boro rice cultivation can be observed, but this seems incorrect since it is a nature area.

Based on the feedback from the local experts the following follow-up steps were taken:

- Historical maps and current satellite data shows that the Chittagong region has always contained a lot of forest, therefore the map was not changed despite the feedback from the local expert.
- The Sundarban area was checked using Google Maps Streetview for the occurrence of rice cultivation, which is cultivated in the area. Therefore, no alterations of the land use map in this area were performed.

In addition to the visual assessment, a statistical assessment was performed. The size of the agricultural land use classes per Bangladesh district were compared to the size of the agricultural land use classes derived from statistical data from the Bangladesh Bureau of Statistics[1].

The comparison between the data sets showed starks differences in the various cropping systems of the agricultural area between the data from the Bangladesh Bureau of Statistics and that of the land use map 2020 data (see Annex 1). The area of the cropping systems of the Bangladesh Bureau of Statistics are always larger in size than those of the Bangladesh 2020 map, ranging from 30 percent to almost 600 percent. There are various reasons for this agricultural area difference:

- The datasets from the Bangladesh Bureau of Statistics takes does not take double/triple cropping into account, while the dataset from the land use map dataset does;
- Both datasets rely on different data sources;
- Both datasets were derived through the use of different methods, and
- Both datasets are from different years due to unavailability of data from the same years.

The difference in agricultural area mainly occurs in the combination classes (e.g. the different aman rice classes from the Bangladesh Bureau of Statistics and the aman cropping systems from the land use map 2020: rice aman with maize, rice aman with wheat & fibres, rice aman with aus, rice aman/aus with pulses, rice aman/aus with vegetables & spices). Although the statistical assessment shows large differences in the area of the cropping systems, the spatial patterns of the map are accurate. The scientific contribution of this map is therefore in understanding spatial patterns of cropping systems across Bangladesh and may form the basis for assessing climate vulnerability of crop production (see Annex 2) or projecting cropping system into the future as a result of population growth, urbanization and climate change (see Annex 3).

The land cover database is freely available and can be downloaded from the Dhaka Food Systems interactive GIS[2].

[1] http://www.bbs.gov.bd/

[2] https://dhakafoodsystems.wenr.wur.nl/

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Annex 1 Statistical data

Table A1.1 *The total cropping area per district for both data sets and the difference between the two data sets for every district.*

District	Land use map 2020 data	Bangladesh Bureau of Statistics data	Deviation between data sets
Bagerhat	100331	144313	-44%
Bandarban	5492	36901	-572%
Barguna	84657	149575	-77%
Barisal	92159	243031	-164%
Bhola	66159	359805	-444%
Bogra	209175	431912	-106%
Brahamanbaria	140914	240850	-71%
Chandpur	61096	172208	-182%
Chittagong	117026	303149	-159%
Chuadanga	76159	198457	-161%
Comilla	171427	421073	-146%
Cox'S Bazar	61927	138884	-124%
Dhaka	59946	107757	-80%
Dinajpur	300868	716228	-138%
Faridpur	131129	315567	-141%
Feni	43004	112217	-161%
Gaibandha	154183	332623	-116%
Gazipur	57688	109898	-91%
Gopalganj	105484	176598	-67%
Habiganj	192428	465149	-142%
Jamalpur	143834	336834	-134%
Jessore	164555	394461	-140%
Jhalokati	20898	80933	-287%
Jhenaidah	132226	299051	-126%
Joypurhat	82227	210734	-156%
Khagrachhari	12826	56221	-338%
Khulna	124092	162212	-31%
Kishoreganj	190103	293992	-55%
Kurigram	128316	288522	-125%
Kushtia	100800	233884	-132%
Lakshmipur	48697	145523	-199%
Lalmonirhat	89412	187995	-110%
Madaripur	75903	143401	-89%
Magura	72267	186547	-158%
Manikganj	77435	191482	-147%
Maulvibazar	129372	205250	-59%
Meherpur	49726	115471	-132%
Munshiganj	54314	115538	-113%
Mymensingh	290453	579032	-99%
Naogaon	298489	540844	-81%
Narail	68061	159453	-134%
Narayanganj	29845	55303	-85%
Narsingdi	46590	108755	-133%
Natore	137421	314175	-129%
Nawabganj	103818	221039	-113%
Netrakona	240523	311602	-30%
Nilphamari	124448	265450	-113%
Noakhali	92631	277482	-200%
Pabna	166341	382576	-130%

District	Land use map 2020 data	Bangladesh Bureau of Statistics data	Deviation between data sets
Panchagarh	117741	227980	-94%
Patuakhali	157393	242852	-54%
Pirojpur	41361	113358	-174%
Rajbari	68913	178504	-159%
Rajshahi	164888	321017	-95%
Rangamati	27580	34960	-27%
Rangpur	183450	387054	-111%
Satkhira	121943	191005	-57%
Shariatpur	73991	110873	-50%
Sherpur	98976	214285	-117%
Sirajganj	163056	378849	-132%
Sunamganj	320373	296927	7%
Sylhet	241147	293578	-22%
Tangail	185935	422412	-127%
Thakurgaon	166480	396122	-138%

Table A1.2 *Area in hectares for every cropping system in the Bangladesh Bureau of Statistics data set per district.*

District	Aus	T Aman	B Aman	Boro	Wheat	Pulses	Maize Rabi	Maize Kharif	Jute	Spices	OilSeeds	Potato	Sugarcane	Vegetables S	Vegetables W
Bagerhat	5,785	71,500	455	50,831	166	4,904	143	-	1,149	831	684	989	622	2,614	3,640
Bandarban	12,108	11,303	-	6,302	-	125	143	160	-	1,596	125	549	85	2,609	1,796
Barguna	41,820	100,632	-	415	-	4,368	52	-	-	509	37	274	48	499	921
Barisal	17,271	128,029	819	52,339	517	22,885	130	-	11,318	1,839	744	1,540	435	2,017	3,148
Bhola	86,800	175,200	-	45,568	1,408	23,255	158	-	-	14,919	857	7,330	362	1,421	2,527
Bogra	19,075	164,380	-	187,013	2,677	776	4,945	639	6,584	7,000	16,185	15,214	271	3,102	4,051
Brahamanbaria	8,115	67,610	21,250	121,851	706	1,873	-	30	2,731	1,979	7,902	2,000	16	1,567	3,220
Chandpur	9,955	43,045	18,355	67,733	316	710	6,089	785	4,411	3,953	1,586	10,260	578	1,114	3,318
Chittagong	35,528	175,475	-	61,651	-	4,217	25	-	-	4,371	321	4,805	1,144	6,206	9,406
Chuadanga	38,400	34,190	-	38,730	671	2,945	44,895	63	22,286	2,369	1,792	1,438	1,976	3,794	4,908
Comilla	70,800	135,155	28,455	144,736	1,447	1,057	8,035	-	421	4,430	3,004	11,634	376	3,927	7,596
Cox'S Bazar	3,572	77,765	-	50,566	-	227	-	-	-	1,126	154	2,000	306	1,206	1,962
Dhaka	747	16,716	7,960	47,156	267	2,154	4,256	334	5,206	2,160	9,822	1,906	59	3,594	5,420
Dinajpur	7,708	256,410	-	175,290	9,665	500	56,360	5,430	8,539	6,971	12,343	165,587	1,878	3,197	6,350
Faridpur	6,580	82,090	16,870	27,804	27,849	21,053	365	-	82,434	32,599	7,980	298	4,144	2,476	3,025
Feni	8,461	65,215	-	33,480	18	1,911	36	-	-	444	221	257	104	839	1,231
Gaibandha	1,608	117,300	-	125,099	2,962	1,108	11,041	187	12,694	2,380	1,931	49,146	2,414	2,452	2,301
Gazipur	1,356	42,502	362	54,316	-	348	2	15	1,574	1,478	1,598	138	1,216	2,207	2,786
Gopalganj	3,355	27,580	16,020	73,311	7,202	12,035	33	-	24,807	3,314	3,675	304	707	2,071	2,184
Habiganj	45,120	102,000	27,000	108,124	543	117	6	-	344	620	798	175,273	985	1,457	2,762
Jamalpur	1,770	99,880	-	131,138	5,521	1,325	8,394	-	40,045	9,307	9,322	14,838	5,064	2,380	7,850
Jessore	20,500	126,035	-	160,106	282	12,844	351	-	28,878	3,857	8,917	16,226	384	7,650	8,431
Jhalokati	13,355	50,500	-	9,800	105	2,719	57	-	-	624	230	426	121	1,090	1,906
Jhenaidah	30,400	99,163	8	86,317	2,662	13,517	14,944	-	24,083	9,725	3,063	3,521	801	5,115	5,732
Joypurhat	251	70,670	-	68,035	1,200	263	271	76	2,855	1,311	2,335	59,622	893	1,549	1,403
Khagrachhari	4,312	28,167	-	10,095	-	113	382	142	-	4,224	142	565	248	4,468	3,363
Khulna	3,280	95,295	5,025	48,811	211	310	22	-	1,991	606	284	1,578	40	1,902	2,857
Kishoreganj	24,135	77,020	-	158,184	565	673	3,766	-	15,795	2,733	673	5,445	24	1,830	3,149
Kurigram	1,460	115,077	-	117,321	8,930	2,244	7,409	503	17,321	1,838	4,153	6,876	288	2,316	2,786
Kushtia	27,800	84,437	110	28,508	8,754	10,617	6,280	202	41,368	12,814	2,661	473	3,596	2,813	3,451
Lakshmipur	28,160	77,615	5,200	26,411	3	1,428	-	-	36	2,106	90	263	138	1,628	2,445
Lalmonirhat	5,037	84,510	-	47,851	1,611	194	26,116	5,270	4,174	1,469	779	6,594	112	1,550	2,728
Madaripur	1,525	26,511	15,150	33,677	5,181	11,216	62	-	31,991	8,038	6,616	512	106	1,083	1,733
Magura	3,310	58,715	1,065	42,696	4,287	18,992	48	-	40,150	8,015	4,681	2,431	119	934	1,104

District	Aus	T Aman	B Aman	Boro	Wheat	Pulses	Maize Rabi	Maize Kharif	Jute	Spices	OilSeeds	Potato	Sugarcane	Vegetables S	Vegetables W
Manikganj	1,422	38,891	32,000	46,533	2,643	4,987	16,297	4,806	5,160	11,212	18,690	1,533	1,856	1,911	3,541
Maulvibazar	45,777	97,890	1,955	52,943	77	167	4	-	-	542	298	1,881	52	1,619	2,045
Meherpur	15,200	25,630	-	13,627	6,610	7,764	8,512	-	25,907	2,692	5,314	29	376	2,210	1,600
Munshiganj	94	20,745	20,235	26,450	11	242	56	854	3,265	820	2,176	36,319	120	1,763	2,388
Mymensingh	16,626	259,040	-	266,243	1,269	1,443	117	-	6,836	3,778	2,384	4,912	2,276	6,565	7,543
Naogaon	59,190	164,152	3,050	199,007	27,975	798	6,209	1,052	6,824	5,031	21,785	38,268	503	3,153	3,847
Narail	5,459	39,975	5,290	59,063	1,645	16,424	-	-	22,060	1,702	2,518	1,296	720	1,385	1,916
Narayanganj	690	10,883	7,730	26,018	3	297	27	-	408	628	736	3,011	59	1,859	2,954
Narsingdi	331	41,483	1,083	50,213	942	310	15	-	2,981	1,648	1,562	1,344	52	2,137	4,654
Natore	6,855	74,123	17,665	59,225	19,014	24,449	4,765	1,000	24,318	28,565	2,216	22,539	24,475	2,276	2,690
Nawabganj	52,630	48,828	-	47,079	24,924	21,279	5,114	614	1,167	5,631	7,734	59	1,483	1,772	2,725
Netrakona	490	122,395	-	171,875	1,611	208	-	-	5,081	1,297	936	3,944	25	1,707	2,033
Nilphamari	406	111,808	-	101,166	4,939	161	18,911	2,522	10,028	4,840	894	4,730	77	2,039	2,929
Noakhali	37,321	144,652	207	76,035	-	9,292	-	-	-	4,412	17	82	91	1,515	3,858
Pabna	16,974	94,727	42,515	56,317	25,405	17,640	695	37	44,371	54,741	15,708	1,475	3,381	4,930	3,660
Panchagarh	280	97,490	-	35,308	22,051	310	18,494	506	10,917	8,217	1,087	22,834	3,927	2,523	4,036
Patuakhali	28,729	201,213	-	1,075	60	8,400	46	-	-	1,293	40	467	35	624	870
Pirojpur	14,825	65,157	2,790	21,871	35	2,817	253	-	344	552	39	1,066	153	1,226	2,230
Rajbari	1,310	46,256	2,530	12,664	11,985	10,030	95	14	48,278	35,667	1,078	170	1,323	3,160	3,944
Rajshahi	47,069	71,114	-	69,175	22,129	28,593	5,039	8,317	14,158	17,395	15,190	849	9,975	3,996	8,018
Rangamati	6,420	9,133	-	6,878	-	262	208	278	-	4,586	203	88	231	3,397	3,276
Rangpur	16,075	163,461	-	141,693	2,705	634	16,584	8,463	11,118	5,390	1,910	10,116	1,652	3,384	3,869
Satkhira	6,350	84,685	-	71,468	1,001	1,840	64	-	11,630	1,598	5,370	32	125	3,078	3,764
Shariatpur	9,180	17,669	9,250	21,172	3,936	6,143	21	-	25,048	8,210	4,935	1,999	433	1,093	1,784
Sherpur	2,240	88,350	-	107,306	639	728	626	-	2,308	2,129	2,138	1,869	91	2,457	3,404
Sirajganj	4,725	82,800	19,175	139,338	5,861	5,504	9,333	44	13,535	3,086	48,795	39,950	1,116	2,145	3,442
Sunamganj	12,452	74,327	57	201,037	560	243	-	-	953	649	526	2,004	134	767	3,218
Sylhet	60,825	141,920	3,175	77,916	350	71	12	-		642	1,002	1,663	8	1,596	4,398
Tangail	837	116,482	32,645	191,878	6,069	8,381	2,201	-	19,650	5,005	22,647	3,040	1,390	5,113	7,074
Thakurgaon	14,820	136,485	-	67,529	61,038	593	18,240	21,369	8,686	1,488	3,878	51,167	4,361	2,980	3,488
Bangladesh Total	**17,893**	**82,803**	**455**	**57,133**	**166**	**5,029**	**286**	**160**	**1,149**	**2,427**	**809**	**1,538**	**707**	**5,223**	**5,436**

Table A1.3 *Area in hectares for every cropping system in the land use map 2020 data set per district.*

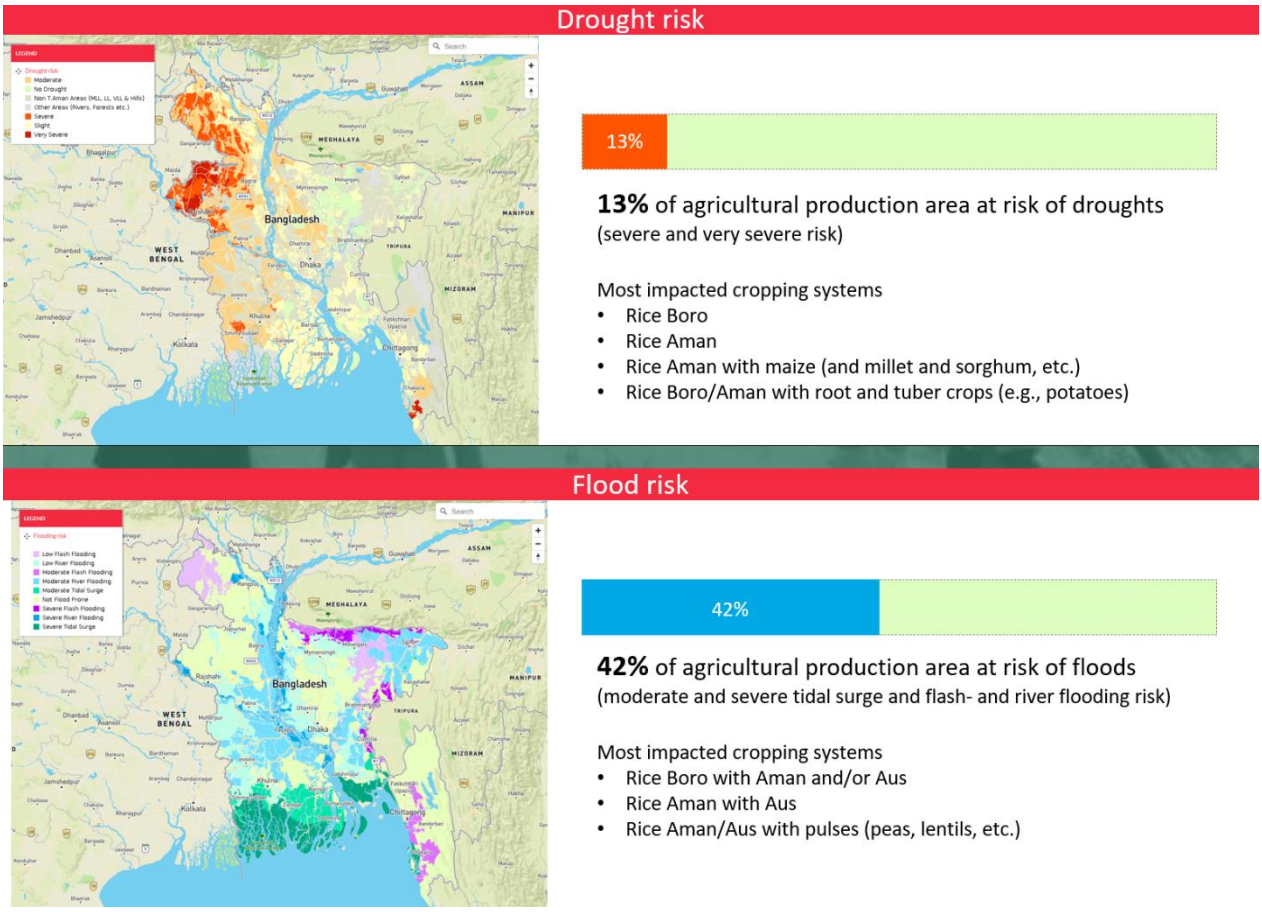
District	Rice Boro	Rice Aman	Rice Aman with Maize	Rice Aman with Wheat and Fibres	Rice Aus	Rice Aman with Aus	Rice Aman/Aus with Pulses	Rice Aman/Aus with Vegetables and Spices	Rice Boro With Aman and/or Aus	Rice Boro/Aman with Root-/Tubercrops	Rice Boro/Aman with Fish	Vegetables; Spices and others crops
Bagerhat	174,610,000	43,850,000	430,000	99,260,000	6,480,000	18,910,000	180,110,000	73,670,000	271,010,000	9,580,000	37,940,000	87,460,000
Bandarban	17,210,000	6,730,000	550,000	1,590,000	1,010,000	1,000,000	6,870,000	7,160,000	7,380,000	-	30,000	5,390,000
Barguna	110,580,000	72,650,000	-	277,940,000	4,710,000	57,780,000	71,900,000	35,740,000	167,460,000	-	170,000	47,640,000
Barisal	169,740,000	19,540,000	-	28,910,000	2,730,000	7,220,000	320,360,000	93,390,000	197,200,000	8,830,000	9,660,000	64,010,000
Bhola	74,120,000	221,650,000	-	-	4,480,000	78,730,000	20,110,000	20,680,000	202,240,000	-	15,930,000	23,650,000
Bogra	195,430,000	78,800,000	69,210,000	42,570,000	12,240,000	85,670,000	167,530,000	430,980,000	279,690,000	597,140,000	2,130,000	130,360,000
Brahamanbaria	311,010,000	20,710,000	-	361,810,000	9,420,000	56,700,000	-	133,630,000	146,800,000	201,210,000	15,330,000	152,520,000
Chandpur	145,190,000	32,230,000	-	33,430,000	14,010,000	22,350,000	65,070,000	47,580,000	128,140,000	45,330,000	11,430,000	66,200,000
Chittagong	123,390,000	77,280,000	3,540,000	6,600,000	1,930,000	14,350,000	551,440,000	130,470,000	191,210,000	-	1,770,000	68,280,000
Chuadanga	267,630,000	53,460,000	38,390,000	89,310,000	5,240,000	14,100,000	-	44,450,000	131,810,000	60,000	220,000	116,920,000
Comilla	245,820,000	285,700,000	-	162,200,000	27,880,000	58,500,000	-	404,990,000	333,090,000	5,080,000	29,460,000	161,550,000
Cox'S Bazar	108,050,000	162,310,000	17,820,000	29,030,000	5,890,000	28,360,000	16,290,000	64,270,000	132,400,000	-	7,160,000	47,690,000
Dhaka	110,620,000	7,710,000	89,690,000	46,830,000	1,880,000	10,640,000	29,900,000	160,460,000	62,480,000	-	1,130,000	78,120,000
Dinajpur	413,540,000	53,980,000	578,310,000	43,280,000	3,530,000	111,890,000	342,120,000	513,560,000	347,400,000	399,640,000	340,000	201,090,000
Faridpur	250,540,000	29,890,000	6,550,000	12,280,000	2,090,000	3,680,000	428,410,000	214,830,000	210,660,000	17,490,000	790,000	134,080,000
Feni	55,870,000	121,300,000	-	-	5,210,000	40,800,000	19,730,000	45,310,000	107,360,000	-	7,710,000	26,750,000
Gaibandha	228,040,000	189,150,000	40,390,000	300,600,000	18,250,000	82,390,000	4,630,000	151,480,000	349,730,000	29,740,000	6,170,000	141,260,000
Gazipur	103,110,000	1,890,000	21,660,000	192,500,000	330,000	19,030,000	-	89,520,000	72,070,000	-	9,950,000	66,820,000
Gopalganj	174,770,000	5,410,000	-	125,620,000	3,990,000	39,540,000	126,940,000	121,190,000	71,700,000	293,290,000	980,000	91,410,000
Habiganj	496,890,000	415,320,000	-	86,840,000	43,600,000	102,650,000	-	123,840,000	465,740,000	1,210,000	1,700,000	186,490,000
Jamalpur	199,010,000	68,840,000	2,760,000	3,250,000	7,230,000	15,630,000	474,710,000	199,310,000	332,490,000	1,230,000	18,240,000	115,640,000
Jessore	275,720,000	61,210,000	1,910,000	108,780,000	2,920,000	16,030,000	574,730,000	175,900,000	291,880,000	90,000	29,990,000	106,390,000
Jhalokati	23,060,000	13,740,000	-	970,000	870,000	5,750,000	32,410,000	16,740,000	107,390,000	-	80,000	7,970,000
Jhenaidah	273,330,000	41,310,000	21,230,000	417,100,000	980,000	39,730,000	28,370,000	108,540,000	227,210,000	36,160,000	470,000	127,830,000
Joypurhat	123,060,000	10,920,000	3,140,000	52,410,000	1,690,000	26,570,000	-	23,890,000	78,860,000	418,370,000	3,700,000	79,660,000
Khagrachhari	20,500,000	21,410,000	-	-	1,400,000	3,660,000	31,350,000	20,860,000	18,650,000	-	-	10,430,000
Khulna	187,980,000	11,730,000	16,700,000	29,010,000	1,490,000	3,570,000	485,290,000	116,810,000	294,380,000	-	20,070,000	73,890,000
Kishoreganj	591,120,000	139,420,000	-	103,990,000	37,280,000	50,510,000	-	361,910,000	367,390,000	2,180,000	44,720,000	202,510,000
Kurigram	228,100,000	48,300,000	74,990,000	402,630,000	8,700,000	62,090,000	12,860,000	78,860,000	232,260,000	5,260,000	8,510,000	120,600,000
Kushtia	200,490,000	25,110,000	208,820,000	30,780,000	680,000	11,200,000	20,050,000	223,440,000	176,600,000	4,980,000	1,560,000	104,290,000
Lakshmipur	56,420,000	12,410,000	-	181,820,000	750,000	81,320,000	27,270,000	19,900,000	82,080,000	660,000	3,110,000	21,230,000
Lalmonirhat	176,500,000	1,570,000	96,690,000	263,100,000	630,000	44,860,000	470,000	89,190,000	100,280,000	17,580,000	1,530,000	101,720,000

District	Rice Boro	Rice Aman	Rice Aman with Maize	Rice Aman with Wheat and Fibres	Rice Aus	Rice Aman with Aus	Rice Aman/Aus with Pulses	Rice Aman/Aus with Vegetables and Spices	Rice Boro With Aman and/or Aus	Rice Boro/Aman with Root-/Tubercrops	Rice Boro/Aman with Fish	Vegetables; Spices and others crops
Madaripur	188,160,000	47,610,000	1,590,000	13,420,000	7,660,000	11,730,000	90,160,000	125,510,000	136,320,000	18,790,000	500,000	117,580,000
Magura	123,030,000	124,760,000	10,600,000	46,360,000	4,950,000	21,610,000	67,170,000	69,760,000	176,550,000	15,730,000	180,000	61,970,000
Manikganj	158,100,000	46,550,000	19,050,000	50,080,000	7,610,000	10,590,000	96,510,000	116,490,000	160,350,000	-	910,000	108,110,000
Maulvibazar	277,140,000	299,360,000	-	35,660,000	31,350,000	82,750,000	-	112,480,000	337,200,000	-	2,250,000	115,530,000
Meherpur	158,780,000	30,950,000	36,750,000	58,820,000	1,780,000	11,500,000	18,760,000	14,990,000	86,070,000	-	40,000	78,820,000
Munshiganj	144,520,000	36,940,000	23,800,000	2,560,000	12,620,000	11,030,000	14,790,000	89,360,000	89,300,000	-	6,940,000	111,280,000
Mymensingh	339,390,000	523,570,000	-	276,000,000	72,040,000	222,370,000	13,510,000	248,570,000	939,400,000	-	60,140,000	209,540,000
Naogaon	422,140,000	183,490,000	16,330,000	925,520,000	13,380,000	206,750,000	47,620,000	321,260,000	525,200,000	78,120,000	690,000	244,390,000
Narail	113,370,000	60,240,000	13,130,000	12,630,000	9,480,000	26,430,000	98,650,000	72,140,000	200,950,000	21,950,000	510,000	51,130,000
Narayanganj	66,960,000	26,610,000	6,000,000	29,250,000	7,160,000	7,730,000	-	45,640,000	52,780,000	-	740,000	55,580,000
Narsingdi	86,700,000	18,520,000	-	148,140,000	3,220,000	19,070,000	-	34,950,000	89,100,000	-	8,260,000	57,940,000
Natore	261,240,000	5,110,000	30,660,000	126,980,000	1,120,000	33,250,000	101,640,000	214,100,000	72,850,000	389,040,000	4,650,000	133,570,000
Nawabganj	223,130,000	29,270,000	30,000	378,150,000	2,370,000	48,020,000	23,220,000	73,840,000	157,220,000	-	2,230,000	100,700,000
Netrakona	566,700,000	311,630,000	-	251,840,000	43,920,000	198,220,000	-	121,240,000	643,850,000	53,250,000	1,400,000	213,180,000
Nilphamari	202,220,000	47,460,000	68,870,000	192,600,000	11,400,000	101,580,000	1,370,000	115,230,000	157,460,000	250,680,000	650,000	94,960,000
Noakhali	114,600,000	211,170,000	-	57,510,000	8,330,000	113,230,000	3,100,000	54,570,000	297,030,000	-	22,430,000	44,340,000
Pabna	257,520,000	15,250,000	87,900,000	6,680,000	1,260,000	5,100,000	628,080,000	224,850,000	294,350,000	640,000	13,800,000	127,980,000
Panchagarh	271,480,000	24,940,000	80,330,000	384,770,000	1,830,000	69,520,000	190,000	75,530,000	136,150,000	19,370,000	110,000	113,190,000
Patuakhali	151,780,000	178,170,000	-	54,460,000	5,660,000	88,750,000	606,800,000	117,820,000	311,500,000	-	1,210,000	57,780,000
Pirojpur	55,360,000	34,840,000	-	9,130,000	3,330,000	16,010,000	87,320,000	33,340,000	148,770,000	2,150,000	610,000	22,750,000
Rajbari	125,410,000	61,570,000	43,050,000	15,620,000	2,610,000	7,290,000	123,740,000	89,870,000	150,860,000	-	830,000	68,280,000
Rajshahi	265,650,000	137,560,000	130,690,000	129,710,000	11,980,000	42,510,000	2,530,000	401,280,000	336,260,000	13,990,000	19,890,000	156,830,000
Rangamati	50,040,000	17,540,000	-	-	12,840,000	2,080,000	71,250,000	28,070,000	76,190,000	-	-	17,790,000
Rangpur	304,910,000	21,440,000	279,630,000	24,800,000	2,020,000	43,840,000	64,180,000	420,880,000	183,740,000	310,310,000	820,000	177,930,000
Satkhira	278,610,000	150,670,000	-	174,920,000	4,090,000	4,570,000	91,410,000	73,850,000	253,960,000	5,320,000	46,910,000	135,120,000
Shariatpur	219,540,000	53,430,000	3,140,000	2,130,000	7,760,000	6,710,000	97,250,000	120,130,000	109,390,000	-	1,270,000	119,160,000
Sherpur	134,690,000	219,830,000	-	-	25,880,000	75,290,000	38,320,000	95,720,000	332,200,000	-	700,000	67,130,000
Sirajganj	238,150,000	143,420,000	22,560,000	216,640,000	16,540,000	67,790,000	147,730,000	181,570,000	422,420,000	21,910,000	7,970,000	143,860,000
Sunamganj	1,448,530,000	390,660,000	-	16,380,000	44,560,000	114,730,000	-	119,870,000	550,970,000	30,000	41,380,000	476,620,000
Sylhet	452,050,000	376,550,000	440,000	50,000	42,910,000	154,620,000	-	390,220,000	810,700,000	-	7,970,000	175,960,000
Tangail	256,960,000	101,330,000	-	235,250,000	15,870,000	64,190,000	300,920,000	376,760,000	359,060,000	-	3,450,000	145,560,000
Thakurgaon	394,980,000	7,920,000	110,520,000	253,120,000	820,000	70,020,000	33,000,000	102,140,000	173,360,000	361,100,000	50,000	157,770,000
Bangladesh Total	14,483,290,000	6,293,890,000	2,277,850,000	7,663,620,000	677,870,000	3,174,090,000	6,908,140,000	9,024,580,000	14,956,550,000	3,657,490,000	551,470,000	6,932,180,000

Annex 2 Maps of drought and flood risk in agricultural areas

Authors: Petros Panteleon and Peter Verweij

To determine climate vulnerability estimates for agricultural cropping systems, an overlay of maps from Bangladesh Space Research and Remote Sensing Organisation (SPARRSO) on drought and flood risk with the agricultural cropping systems map was made. The total affected agricultural area for drought risk is 13% and for flood risk is 42%.



Annex 3 Projected cropping systems map

Authors: Charlotte van Haren, Peter Verweij, Michiel van Eupen, Marian Vittek, Saeed Moghayer and Anouk Cormont

Dhaka will experience a rapidly growing population from 20 million in 2019 to a projected 35 million in 2035 (Fan, 2017), which leads to expansion of urban areas and loss of agricultural, food producing, lands (Razi, 2020; Hassan & Southworth, 2017). Through the loss of agricultural land, food for Dhaka's citizens will ultimately be transported over larger distances, putting even more stress on Dhaka's already pressured infrastructure.

Not only Dhaka is growing, all of Bangladesh experiences population and economic growth, leading to land conversion: urbanisation, agricultural expansion at the cost of natural ecosystems and farming intensification associated with loss of fertile soil and contamination. These land-use changes put pressure on the sustainability of the Dhaka food system.

Furthermore, the country's land-use is affected through climate change effects such as sea level rise, salinization, floods, and droughts (Islam et al., 2019; Rahman & Islam, 2019). These natural disturbances impact the local livelihoods and the food production and transportation for Dhaka residents, thereby putting the sustainability of the Dhaka food system under even more pressure.

The development of a Bangladesh's projected land-use map for 2050 is a first step towards understanding Bangladesh's projected land-use change and the potential effect it will have on the Dhaka food system. The map gives an impression of which land-use types will increase at the costs of others and where the land-use change will occur. We used the Conversion of Land Use and its Effects (iCLUE) model (Verweij et al., 2018) to project the spatial land-use map based on future socio-economic, climate, dietary and policy drivers.

iCLUE inputs

Drivers
The socio-economic and biophysical drivers that determine the land-use of every land-use cell consists of multiple categories: soil, climate, accessibility, ground water levels and elevation. The individual driver datasets were ideally available on a 100x100 meter resolution, if this was not possible, data of a coarser resolution was used. The drivers were tested on their correlation against each other, whereby highly correlated drivers were removed from the input parameters.

Scenario
Scenarios are illustrations of possible images of alternative futures (Bishop et al., 2007). In this study, the projected future scenario was developed through combining the Shared Socio-economic Pathway (SSP) 2 and Representative Concentration Pathway (RCP) 4.5.

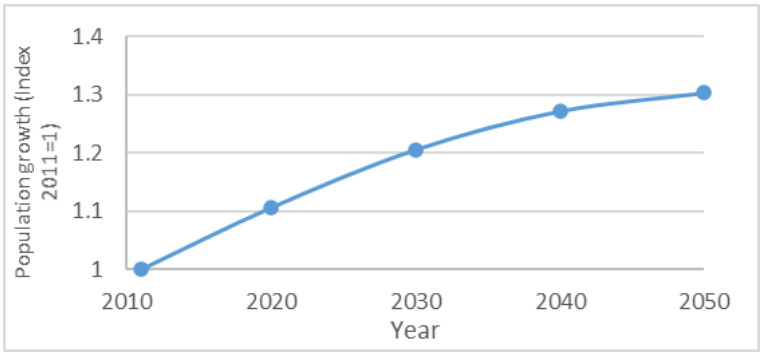


Figure A3.1 *Bangladesh population growth (source: World bank).*

The SSP2 scenario was developed from the SSP scenarios, which were created to characterize a future projection in which trends in society determine whether mitigation of, or adaptation to, climate change becomes easier or harder (O'Neill et al., 2017). The population growth trajectory in this scenario is presented in Figure A3.2. Bangladesh shows a consistently increase in growth and is expected to experience faster growth in population during 2030-2050. As shown in Figure A3.3, Bangladesh's economy in terms of GDP is expected to constantly increase in the period 2011-2050 with more than 700% growth by 2050.

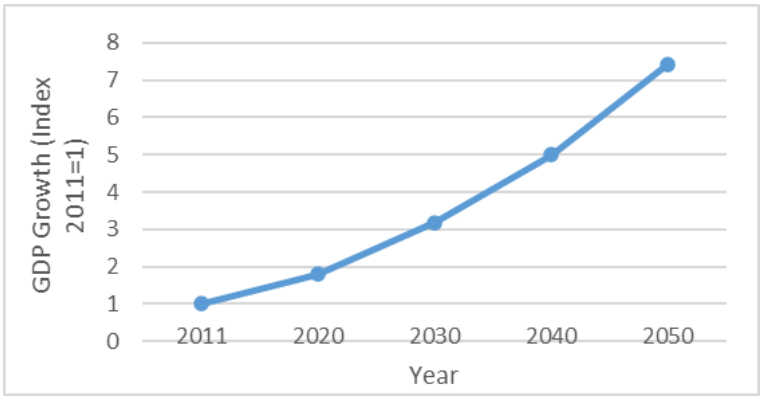


Figure A3.2 *Bangladesh GDP growth (source: World bank).*

The MAGNET model is a global equilibrium model that simulates the impacts of agriculture, trade, land and bioenergy policies on the global economy[3]. In MAGNET supplies of endowment commodities including labour, capital, and natural resources in Bangladesh are exogenously given in the model. Supply of labour including skilled labour and unskilled labour is assumed to follow population growth trajectories. Thus, assumptions on the supply of these primary factors are in nature consistent with the above GDP and population projections. MAGNET projected that agri-food production and consumption increase in SSP2 (see Figure A3.3).

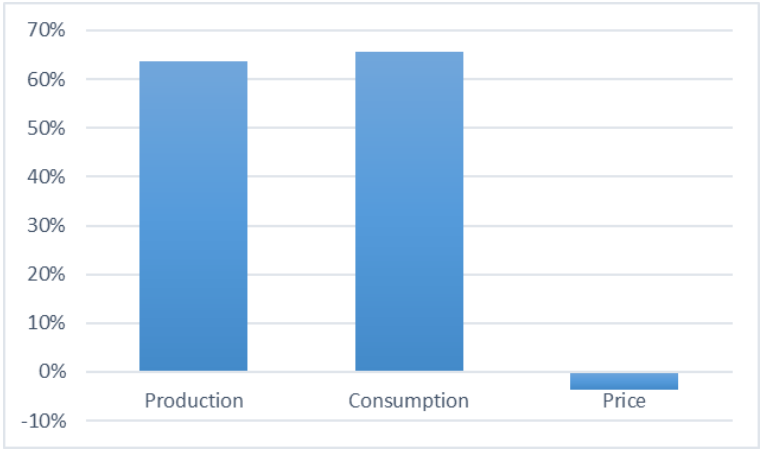


Figure A3.3 *Percentage change in production, consumption and price of agri-food commodities in 2050 compared to the base year (2011).*

The SSPs do not explicitly take climate change into consideration (O'Neill et al., 2017). SSP2 is a middle of the road scenario that projects a future in which social, economic and technological trends follow their historical trends. In SSP2, some investments in energy renewables are done, but at the same time, the reliance on fossil fuels remains. In addition, environmental degradation takes place, although there are some regulations which slow the decline of deforestation and the agricultural sector sees technological innovations at a medium pace.

[3] MAGNET, https://www.magnet-model.org/

RCP 4.5, as a part of the RCP scenarios considers the development of greenhouse gas concentrations and the effect thereof on climate change without considering mitigation options (Moss et al., 2010). RCP 4.5 considers an intermediate future. Under RCP 4.5, the greenhouse gas emissions peak at 2040 and will decline afterwards. By 2100, half of the emission levels in 2050 will be reached.

Land-use demands

The combined SSP2 and RCP 4.5 scenario was used to determine the input parameters for the macro-economic general equilibrium model MAGNET (Doelman et al., 2018), which resulted in agricultural land demands for iCLUE. Map of the Spatial Production Allocation Model (MAPSPAM) has downscaled census data to make estimates of crop distributions at a gridded 5 arc-minute resolution (about 10x10 km resolution) (Yu et al., 2020). By overlaying a MAPSPAM commodity map with the baseline land-use map, the commodity distribution over the land-use classes was derived. The resulting distribution key was then multiplied with projected areal commodity demands from MAGNET to calculate the corresponding areal land-use class demands (see Figure A3.4). The other land demands were derived through statistical extrapolation based on past land-use demands from the Food and Agricultural Organisation of the United Nations (FAO) statistics (see Table A3.1). A MAGNET expert, from Wageningen Economic Research, interpreted the scenario to create the MAGNET model parameters, while an FAO statistics expert interpreted the scenario to develop demands for the other land-use classes.

Year	Artificial surfaces (including urban and associated areas)	Mangroves	Shrublands/or herbaceous vegetation, aquatic or regularly flooded	Tree-covered areas	Grand Total
2001	975	6558	5746	38306	51586
2002	976	6442	5448	38629	51495
2003	980	6307	5507	38022	50816
2004	986	6286	5489	38237	50998
2005	987	6300	5497	37894	50678
2006	991	6304	5604	37411	50310
2007	994	6305	5638	37201	50139
2008	997	6290	5665	36875	49826
2009	1002	6252	5703	36552	49509
2010	1008	6220	5768	36272	49269
2011	1015	6215	5907	36430	49567
2012	1021	6218	6048	36035	49322
2013	1023	6226	6201	35843	49293
2014	1031	6170	6488	35712	49401
2015	1038	6195	6752	35693	49679
2016	1046	6262	7100	35626	50034
2017	1058	6344	7184	35849	50436
2018	1077	6349	7625	35093	50144
Total per class	**18206**	**113243**	**109372**	**661681**	**902502**

Table A3.1 *Size of non-agricultural classes from FAO statistics in km2.*

Transition rules and neighbourhood function

There were two transition rules implemented in the iCLUE run, the classes Built Up-area and Urban dense could both not change to another land-use classes. Thereby, the existing built-up and urban dense present in 2020 remained in the same places in 2050. For the neighbourhood function, the built-up and urban dense classes both incentive additional built-up and urban dense areas to be placed around existing built-up and urban dense area.

iClue land use classes for the food system of Dhaka, Bangladesh	Area [hectare]	Share [%]	Beef Cattle	Dairy Cows	Rice	Horticulture	oil crops	Sugar	Other Crops	Cereals	Wheat	Wol	Cattle Sheep Goat Horse	Energy
Shrubs	28099	0.2%	0.1%	0.1%								2.5%	0.2%	3.3%
Herbaceous vegetation	64834	0.5%	0.4%	0.4%								5.9%	0.5%	
Rice Boro	1319223	9.6%	15.9%	15.9%	26.6%							11.9%	13.0%	
Rice Aman	569255	4.1%	8.0%	8.0%	11.5%							5.2%	6.3%	
Rice Aman with Maize (maize, millet, sorhum, etc)	207805	1.5%	3.6%	3.6%	2.1%							1.9%	2.6%	
Rice Aman with Wheat & Fibres (wheat, barley, jute etc)	694345	5.0%	10.3%	10.3%	7.0%					100.0%	100.0%	6.3%	7.8%	81.9%
Rice Aus	61402	0.4%	0.7%	0.7%	1.2%							0.6%	0.6%	
Rice Aman with Aus	287695	2.1%	4.5%	4.5%	5.8%							2.6%	3.1%	
Rice Aman/Aus with Pulses (peas, lentils, etc)	621284	4.5%	7.9%	7.9%	6.3%	23.0%	33.0%					5.6%	7.2%	
Rice Aman/Aus with Vegetables & Spices (lettuce, onions, mustard, sesame, etc)	816294	5.9%	11.6%	11.6%	8.2%	30.3%						7.4%	10.1%	
Rice Boro with Aman and/or Aus	1352160	9.8%	18.7%	18.7%	27.3%							12.2%	15.3%	
Rice Boro/Aman with Root-/Tubercrops(potatoes, etc)	332855	2.4%	5.7%	5.7%	3.4%							3.0%	5.1%	
Rice Boro/Aman with Fish	49902	0.4%	0.6%	0.6%	0.5%							0.5%	0.5%	
Vegetables, Spices and other crops	629844	4.6%	8.2%	8.2%		46.7%	67.0%	100.0%	100.0%			5.7%	6.8%	
Urban dense	29741	0.2%												
Built-up	904715	6.6%												
Bare / sparse vegetation	89202	0.6%	0.5%	0.5%								8.1%	3.7%	
Permanent water bodies	532067	3.9%												
Herbaceous wetland	206784	1.5%	1.5%	1.5%								9.4%	1.7%	
Closed forest (including plantations, fruit trees, palm, etc)	2242953	16.3%												
Open forest (including plantations, fruit trees etc)	1252995	9.1%	1.8%	1.8%								11.3%	15.5%	14.8%
Mangroves dense	200630	1.5%												
Mangroves open	104383	0.8%												
Open sea	1203182	8.7%												
Total	13801649	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Distribution of MAGNET commodities expressed in areal demands, to land use based on gridded livestock data FAO (glw3, e.g. animal heads per hectare), downscaled crops statistics map spam and Bangladesh land cover map

Figure A3.4 *Distribution key for assigning MAGNET commodities to iCLUE land-use classes.*

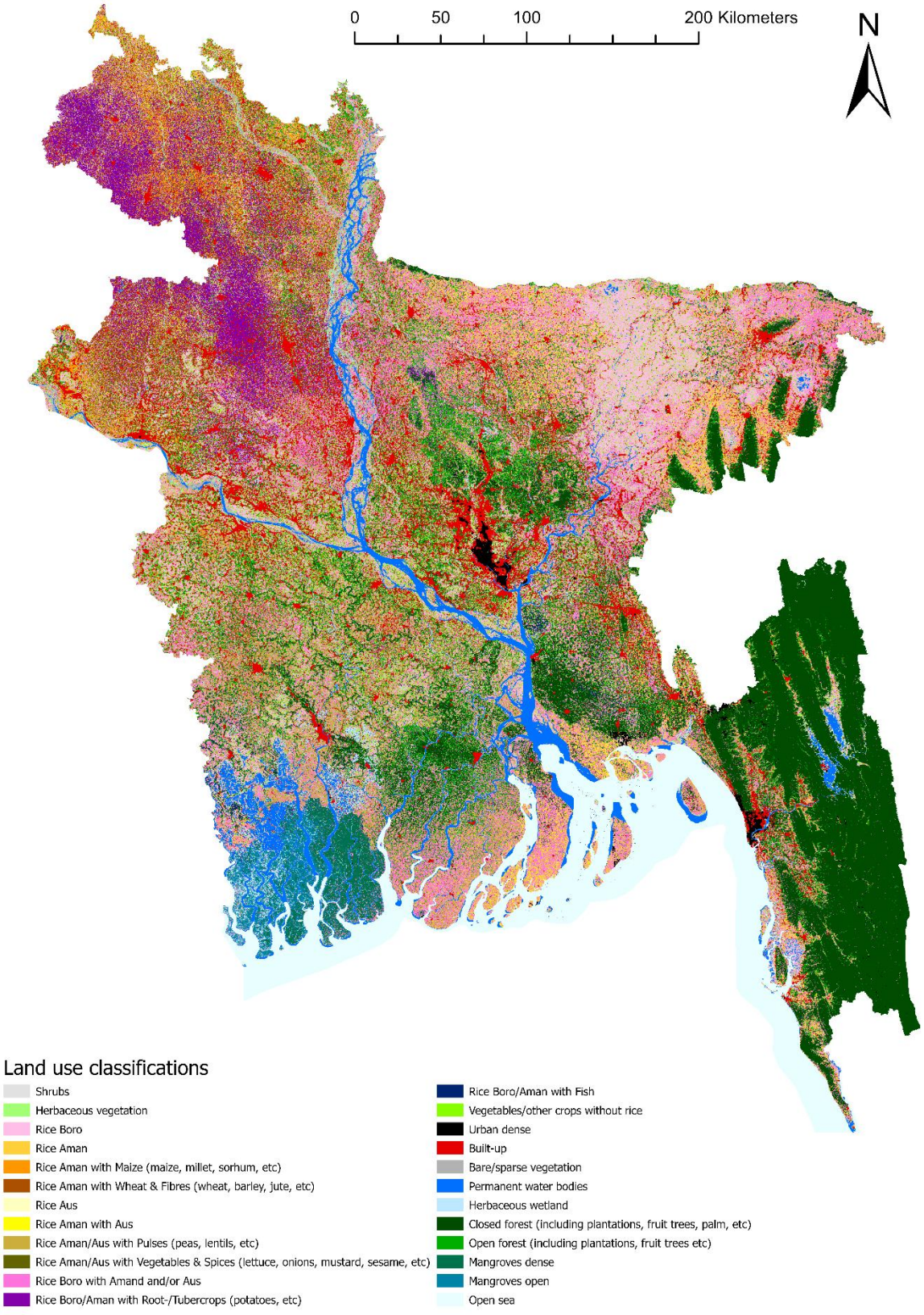


Figure A3.5 *Bangladesh land-use projection for 2050.*

The land-use projection for Bangladesh in 2050 can be seen in Figure A3.5. The projected land-use changes per cells are displayed in Figure A3.6, illustrating that a large part of the country is projected to change from

one land-use class to another. In addition, the figure also shows that despite Rice Boro with Aman and/or Aus increasing in the eastern and southern parts, a decline of the class occurs in the north-west. The major patterns of change observed for this scenario are a decline of rice based cropping systems in favour of rice in combination with root and tuber cropping systems and deforestation in the coastal area in favour of rice cropping systems. In Figure A3.6 the loss and gain in areas of the different land use classes can be observed. Although some classes (i.e. rice boro with aman and/or aus or rice boro) increase in size, they are projected to be removed from current existing places. Reasons for removal of a class are that another class is more suitable in that spot, based on the implemented drivers, or that there are places were the class is more suitable than where it currently is.

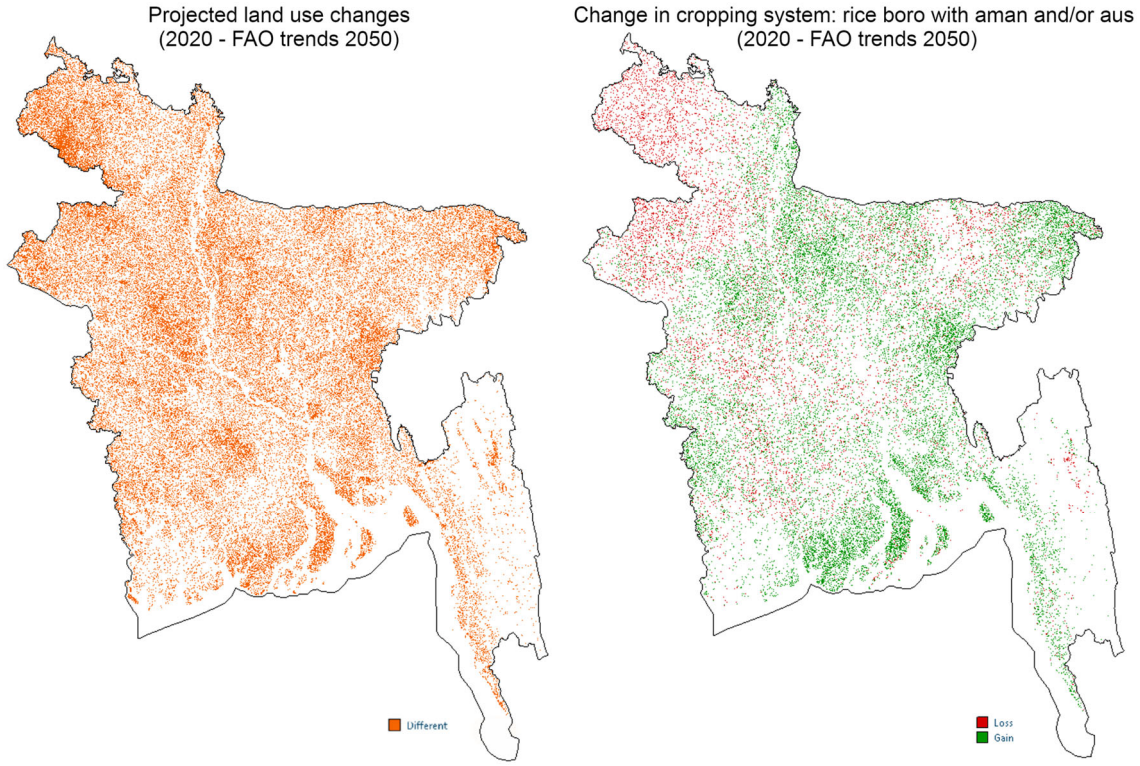


Figure A3.6 *Likely land-use change patterns between 2020 and 2050 given the FAO trend extrapolation scenario.*

Wageningen Environmental Research
P.O. Box 47
6700 AA Wageningen
The Netherlands
T 0317 48 07 00
wur.eu/environmental-research

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Wageningen Environmental Research
P.O. Box 47
6700 AB Wageningen
The Netherlands
T +31 (0) 317 48 07 00
wur.eu/environmental-research

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