GIS-based Land Suitability Assessment of Chickpea and Lentil in Bangladesh[1]

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Abstract

Crop-land suitability analysis is a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. In this study, an attempt has been made to assess the suitability of land thereby identify the potential to expand pulse cultivation. Subsequently, perform spatial analysis to produce maps of constraints and of areas most suited to chickpea and lentil. Limitations for growing chickpea and lentil were assessed; and imposed on the attributes of terrain, soil and climate on the basis of expert knowledge. The evaluation of spatial variability is carried out in terms of suitability ratings from highly suitable to not suitable in GIS environment. Land suitability maps of chickpea and lentil growing area were produced by overlaying the climatic and soil suitability maps. The results of this study can be used for better utilization of land and provided opportunities to harvest full potential of the crop to be grown.

Introduction

Pulses are essential constituents in the food habits of the people of Bangladesh and also vital sources of cheap protein. At present, pulses are grown on area of 0.25 million hectares with total production of 0.23 million metric tonnes (BBS, 2011). Chickpea and lentil are important pulse crops among other pulses grown in Bangladesh. In the year 2010, Bangladesh spends US$257.6 million on importing 0.181 million tonnes chickpea and 0.152 million tonnes lentil pulses (FAOSTAT). In order to reduce the import dependency by increasing domestic production, identification and delineation of suitable areas for growing pulse crops has become imperative so that future research and extension programs can be developed in a realistic manner. Therefore, an attempt has been made under the ACAIR (Australian Centre for International Agricultural Research) project LWR/2005/001, to assess the suitability of land thereby identify the potential to expand pulse cultivation. Subsequently, perform spatial analysis to produce maps of constraints and of areas most suited to chickpea and lentil using Geographic Information System (GIS). However, the study is confined to only agro-edaphic and agro-climatic constraints for pulse production, excluding biotic and socio-economic factors.

The aim of the study was to:

- assess the agro-edaphic, which includes soil, landform and inundation (Land Factors) and agro-climatic constraints in terms of limitations for production of chickpea and lentil ;
- perform land suitability assessment and classification;
- produce land suitability map based on yield potential; and
- delineate potential suitable areas for chickpea and lentil cultivation at district levels.

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The agroecological zone (AEZ) based computerized land resources inventory (LRI) data of Bangladesh Agricultural Research Council (BARC) were used for land suitability assessment of chickpea and lentil in Bangladesh. For this, eleven land factors (soil, inundation, landform) of LRI were considered for suitability assessment and classification. The constraints of each individual land factors for the production of chickpea and lentil were assessed and accordingly degrees of limitation were imposed based on expert judgment who have wide knowledge and field experience on cultivation of crops. Overall suitability rating for land factors is derived by combining limitation ratings using the set of rules based on Zijsvelt's soil-crop suitability model which was introduced in 1979 and revised by Brammer in 1985 and further revised by Hussain et al, 2005. Accordingly, maps of agro-edaphic suitability for chickpea and lentil were produced. Climatic factors which influence crop growth in relation to crop phenology and photosynthesis were also considered in this study. Climate surfaces for minimum temperature and potential evapo-transpiration (PET) were generated and limitations were imposed based on expert consultation. Accordingly, agro-climatic suitability maps for chickpea and lentil were produced. The land suitability assessment for chickpea and lentil was then accomplished by overlaying agro-edaphic and agro-climatic suitability maps.

The land suitability information provided at the 1:250,000 scale and is therefore suitable for broad planning purposes rather than use at the local level. This will eventually assist the researchers and policy makers in developing policy guidelines for the expansion of chickpea and lentil cultivation in Bangladesh. The present study on agro-edaphic and agro-climatic constraints for pulse production also needs to be supported by the analysis of biotic and socio-economic factors affecting the adoption of chickpea and lentil in Bangladesh.

Materials and Methods

The data

The soil, inundation and landform data of land resources inventories of BARC were used for suitability assessment and classification. The climate data maintained at BARC was utilized for climatic analysis. The climate data from 1985 to 2008 were used in this study. The administrative boundaries maps, and soil association by land type grids (LtSoil) of 300 meter pixel size and point shape file of climate stations of (Bangladesh Meteorological Department) BMD and surrounding international stations were used for the study. The mapping scale is 1:250,000. Climate data of international stations was downloaded from the FAOClim-NET (Agroclimatic database management system) website.

Software

The mapped information was prepared by using ArcView 3.2 and Spatial Analyst software. The climate data was summarized using Microsoft Access database. The information on each individual land factor was summarized using SPSS software. Microsoft Excel was used for assigning land factor limitation ratings to each land phase (soil association by land type) pixels and summarizing those to get combined limitation ratings for determining the agro-edaphic suitability for each land phase based on soil-crop suitability model.

Methods

In order to identify major agro-edaphic and agro-climatic constraints to chickpea and lentil cultivation and subsequently perform spatial analysis to produce suitability maps, the following steps were undertaken. The agro-edaphic and agro-climatic suitability was

determined separately based on the land factors and climate. Afterwards, land suitability for chickpea and lentil has been done through overlaying of agro-edaphic and agro-climatic suitability layers. The steps followed under each activity were as follows:

Edaphic Suitability

- Identify major constraint to land factors;
- Apply degrees of limitation to each individual land factor;
- Combine the limitation ratings of different land factors based on soil-crop suitability model to get the agro-edaphic suitability for each land phase (soil association by land type) pixels; and
- Agro-edaphic suitability map composition.

Climate Suitability

- Organize climate data in a required format;
- Create climate surfaces of mean minimum temperature and mean PET;
- Apply degree of limitations to climate surfaces; and
- Agro-climatic suitability map composition based on suitability ratings.

Combined Suitability

- Overlaying of agro-edaphic and agro-climatic suitability maps;
- Land suitability map composition; and
- Delineate areas of chickpea and lentil pulses for each suitability class by districts.

Edaphic Suitability Analysis

To assess agro-edaphic suitability, firstly, the individual land factors in the AEZ land resources database were analyzed using SPSS software to comprehend the crop growing constraints in Bangladesh. The degrees of limitation (with respect to crop requirements) of each individual land factors (Table 2) for the production of chickpea and lentil were assessed. Accordingly, degrees of limitation were imposed to each land factor classes. This was done on a scale of 0-4 and the basis of expert judgment from Dr. Chris Johansen and other experts who have wide knowledge and field experience on cultivation of crops. It is to be noted that in order to assess the suitability of soils for crop production, the soil requirements of crops must be known.

Secondly, a customized program developed in Microsoft Excel software was used to prepare a land utilization table (LUT) on the basis of combined limitation ratings composed of individual land factor constraints for a particular crop. The soil association by land type file (Ltsoil) of LRI, which has 10,471 records (in this study it is named land phase) and contains attributes of 11 land factors (as shown in Table 1), were used for this study. Limitations were assigned to land factors for each land phase via a lookup table. Limitations imposed for different land factors for lentil and chickpea crops are shown in Table 2. Then the degree of limitations assigned to land factors under each land phase was counted. An example of how the values in each category (assigned limitations) are concatenated to get combined limitation ratings is shown in Table 3. Afterwards, an overall suitability rating for each land phase is derived based on the combined limitation ratings using the set of rules as shown in Table 4. This is accomplished based on Zijsvelt's soil-crop suitability model which was introduced in 1979 and revised by Brammer in 1985 and further revised by Hussain et al, 2005.

The next step was to create a database file (.dbf) with LTSOIL, Chickpea_SUIT and Lentil_SUIT fields for joining to the Ltsoil (grid) file using the LTSOIL fields which is common in both the files.

Finally, ArcView 3.2 GIS software was used to generate agro-edaphic suitability maps of chickpea and lentil and delineate areas by different suitability class. To get the edaphic suitability of chickpea and lentil crops, the database file as prepared joined to the Ltsoil (grid) shape file in ArcView using the common fields to generate chickpea and lentil maps.

Climate Suitability Analysis

To carry out the task of agro-climate suitability, the climate data (minimum temperature and PET) for the month of December and January over the period from 1985 to 2008 of BMD and surrounding international stations were used. The climate data has been averaged by climate stations for December and January using MS Access and saved as excel file. The climate files for mean minimum temperature and PET were saved as database file (.dbf) to use in ArcView GIS software. To generate a climate surface the database file was then joined to point shape file (climate stations of BMD and surrounding international stations) using common field Station ID. In the next step the Spatial Analyst software was used for creating surfaces of mean minimum temperature and mean PET. Finally, the degrees of limitation (with respect to crop requirements) for the production of chickpea and lentil were imposed to the climate surfaces on a scale of 0-4 and the basis of expert judgment from Dr. Chris Johansen's to produce climatic suitability maps.

Combined Suitability Analysis

In the final stage of land suitability assessment, the agro-edaphic and agro-climatic suitability maps were overlaid to get the overall land suitability maps of chickpea and lentil pulse crops. The overlaying of suitability maps was done using Map calculator of ArcView GIS software. The rules for combining these maps to get classification of land suitability maps is presented in Table 5. The potential area of chickpea and lentil under each suitability class can be summarized by districts through overlaying of districts boundary and land suitability map layer. In the same way, the potential area for chickpea and lentil under each upazilas can be summarized by suitability class.

Table 1: Land factor classes, code descriptions and ratings

Codes	Land factor description		Rating
p1	Soil permeability	Slow (<12 cm d^{-1})	1
p2		Moderate (12-305 cm d^{-1})	2
p3		Rapid (<305 cm d^{-1})	3
d1	Effective soil depth	<0.25 m	1
d2		0.25 - 0.60 m	2
d3		0.60 - 0.90 m	3
d4		0.90 - 1.22 m	4
d5		>1.22 m	5
d6		Very firm/hard ploughpan	6
m1	Available soil moisture	<100 mm	1
m2		100-200 mm	2
m3		200-300 mm	3
m4		300-400 mm	4
m5		>400 mm	5
n1	Nutrient status	Low	1
n2		High	2
a1	Soil reaction (pH)	pH <4.5	1
a2		pH 4.5-5.5	2
a3		pH 5.5-7.3	3
a4		pH 7.3-8.4	4
a5		pH >8.4	5
s1	Soil salinity	<2 dS m^{-1} or <2 mMhos cm^{-1}	1
s2		2-4 dS m^{-1} or 2-4 mMhos cm^{-1}	2
s3		4-8 dS m^{-1} or 4-8 mMhos cm^{-1}	3
s4		8-15 dS m^{-1} or 8-15 mMhos cm^{-1}	4
s5		>15 dS m^{-1} or >15 mMhos cm^{-1}	5
t1	Soil consistency	not more than slightly firm, slightly sticky, slightly plastic, hard	1
t2		firm, very firm, sticky, plastic, hard, very hard	2
t3		extremely firm, very sticky, very plastic, extremely hard	3
t4		organic material to at least 25 cm below the surface	4
w1	Drainage	Well drained	1
w2		Moderately well-drained	2
w3		Imperfectly drained	3
w4		Poorly drained, surface drains <15 Nov	4
w5		Poorly drained, surface drains >15 Nov	5
w6		Very poorly drained	6
i1	Depth of inundation	No inundation	1
i2		< 30 cm	2
i3		30-90 cm	3
i4		90-180 cm	4
i5		180-300 cm	5
i6		> 300 cm	6
f1	Flood hazards	None	1
f2		Once in 10 years	2
f3		twice in 10 years	3
f4		3-4 times in 10 years	4
f5		5 times or more in 10 years	5
e1	Slope	<3 percent	1
e2		3-8 percent	2
e3		8-16 percent	3
e4		16-30 percent	4
e5		30-45 percent	5
e6		> 45 percent	6

Table 2: Degrees of limitation imposed for different land factors for lentil and chickpea

Codes	Land factors	Degrees of limitation[1]	
		Chickpea	Lentil
p1	Soil permeability	1	1
p2		0	0
p3		3	1
d1	Effective soil depth	4	4
d2		3	3
d3		2	1
d4		0	0
d5		0	0
d6		1	2
m1	Available soil moisture	2	2
m2		0	0
m3		0	0
m4		2	1
m5		2	2
n1	Nutrient status	1	1
n2		0	0
a1	Soil reaction	4	4
a2		3	3
a3		1	1
a4		0	0
a5		2	2
s1	Soil salinity	0	0
s2		3	3
s3		4	4
s4		4	4
s5		4	4

Codes	Land factor	Degrees of limitation[1]	
		Chickpea	Lentil
t1	Soil consistency	0	0
t2		0	1
t3		1	2
t4		0	0
w1	Drainage	0	0
w2		0	0
w3		1	2
w4		3	3
w5		4	4
w6		4	4
i1	Depth of inundation	0	0
i2		0	0
i3		0	0
i4		0	1
i5		3	3
i6		4	4
f1	Flood hazards	0	0
f2		0	0
f3		0	0
f4		0	0
f5		0	0
e1	Slope	0	0
e2		2	2
e3		4	4
e4		4	4
e5		4	4
e6		4	4

[1] **Degrees of limitation: 0 = No limitation, 1 = Moderate, 2 = Severe, 3 = Very severe, 4 = Extremely severe**

Note: To eliminate the effect of Flood Hazard Frequency (f), all classes were assigned a value of '0', which interprets to 'No Limitation'

Table 3: Assigned limitations and number, degree of limitations and suitability

Assigned Limitations											Degree of limitations and Count					COMB_SEV	Suitability
E	D	M	P	W	T	A	N	S	I	F	NONE	MOD	SEV	VSEV	ESEV		Lentil_SUIT
0	2	0	1	3	0	0	1	0	0	1	6	3	1	1	0	6-3-1-1-0	4
0	2	0	1	4	0	0	1	0	4	1	5	3	1	0	2	5-3-1-0-2	5
0	0	0	0	4	0	0	1	0	4	2	7	1	1	0	2	7-1-1-0-2	5
0	0	0	0	4	0	0	1	0	4	3	7	1	0	1	2	7-1-0-1-2	5
0	0	0	0	4	0	0	1	0	4	4	7	1	0	0	3	7-1-0-0-3	5
0	2	0	1	1	0	1	1	0	0	0	6	4	1	0	0	6-4-1-0-0	3
….	…..	..	..	..	..	..	..	..	..	..							
0	0	0	3	4	0	2	1	3	4	2	4	1	2	2	2	4-1-2-2-2	5

None = No limitation, Mod = Moderate limitation, SEV= Severe Limitation, VSEV= Very severe limitation, ESEV= Extremely severe limitation

Table 4: Relationship between suitability rating and number and degree of limitations

Code	**Description**	**Percent MAT** (Maximum Attainable Yield)	**Number and degree of limitations**	**Concatcode 0-1-2-3-4**	**Edaphic Suitability**
S1	Very Suitable	80 percent or more of MAT	All 0	11-0-0-0-0	1
			One 1, and rest 0	10-1-0-0-0	1
			Two 1, rest 0	9-2-0-0-0	1
S2	Suitable	60 to 80 percent of MAT	Three 1, rest 0	8-3-0-0-0	2
			Four 1, rest 0	7-4-0-0-0	2
			One 2, rest 0	10-0-1-0-0	2
			One 2, one 1, rest 0	9-1-1-0-0	2
			One 2, two 1, rest 0	8-2-1-0-0	2
			Two 2, rest 0	9-0-2-0-0	2
S3	Moderately Suitable	40 to 60 percent of MAT	Five 1, rest 0	6-5-0-0-0	3
			Six 1, rest 0	5-6-0-0-0	3
			One 2, three 1, rest 0	7-3-1-0-0	3
			One 2, four 1, rest 0	6-4-1-0-0	3
			Two 2, one 1, rest 0	8-1-2-0-0	3
			Two 2, one 2, rest 0	7-2-2-0-0	3
			Three 2, rest 0	8-0-3-0-0	3
			One 3, rest 0	10-0-0-1-0	3
			One 3, one 1, rest 0	9-1-0-1-0	3
			One 3, two 1, rest 0	9-0-1-1-0	3
			One 3, one 2, rest 0	8-2-0-1-0	3
			One 3, one 2, one 1, rest 0	8-1-1-1-0	3
S4	Marginally Suitable	20 to 40 percent of MAT	Seven 1, rest 0	4-7-0-0-0	4
			Eight 1, rest 0	3-8-0-0-0	4
			Nine 1, rest 0	2-9-0-0-0	4
			One 2, five 1, rest 0	5-5-1-0-0	4
			One 2, six 1, rest 0	4-6-1-0-0	4
			Two 2, three 1, rest 0	6-3-2-0-0	4
			Two 2, four 1, rest 0	5-4-2-0-0	4
			Three 2, one 1, rest 0	7-1-3-0-0	4
			Three 2, two 1, rest 0	6-2-3-0-0	4
			Four 2, rest 0	7-0-4-0-0	4
			One 3, three 1, rest 0	7-3-0-1-0	4
			One 3, four 1, rest 0	6-4-0-1-0	4
			One 3, one 2, two 1, rest 0	7-2-1-1-0	4
			One 3, one 1, three 1, rest 0	6-3-1-1-0	4
			One 3, one 1, four 1, rest 0	5-4-1-1-0	4
			One 3, two 2, rest 0	7-1-2-1-0	4
			One 3, two 2, one 1, rest 0	8-0-2-1-0	4
			Two 3, rest 0	9-0-0-2-0	4
			Two 3, one 1, rest 0	8-1-0-2-0	4
N	Not Suitable	Less than 20 percent of MAT	All other combinations		5

Source: Land Resources Appraisal of Bangladesh, FAO/UNDP (1985)

Table 5: Relationship between Agro-climatic, Agro-edaphic and land suitability classification

Agro-climatic suitability rating	Agro-edaphic suitability rating	Land suitability rating
VS	S1	VS
	S2	S
	S3	MS
	S4	LS
	N	NS
S	S1	S
	S2	MS
	S3	LS
	S4	LS
	N	NS
MS	S1	MS
	S2	LS
	S3	LS
	S4	NS
	N	NS
LS	S1	LS
	S2	LS
	S3	NS
	S4	NS
	N	NS
N	S1	NS
	S2	NS
	S3	NS
	S4	NS
	N	NS

VS=Very Suitable, S=Suitable, MS=Moderately Suitable, LS=Marginally Suitable, NS=Not Suitable

Results and Discussion

In order to assess the land suitability of chickpea and lentil two major components were taken into consideration for this study. These are (i) agro-edaphic (soil, inundation, landform) and agro-climatic (minimum temperature, PET) which are described in the following sections.

Agro-edaphic factors

Eleven edaphic factors are considered to be most dominating crop growing attributes. The individual land factors of LRI were analyzed to get an overview of the edaphic constraints and limitations likely to affect crop performance. The tabular output for land factors thus generated is presented in Table 6.

It was observed that highland (land above normal inundation level), medium highland-1 (land normally inundated to 30 cm depth) and medium highland-2 (land normally inundated 30-90 cm depth) occupies about 74% of the total land area of Bangladesh. In the constraints analysis depth of inundation was taken into consideration and limitation ratings imposed accordingly to address the land type factor for Rabi pulses cultivation. The soil texture

constraints are handled within soil consistency and effective soil depth factors. In Table 6, it is found that silt loam textured soil comprises 31.3% followed by silty clay 18.4% and clay 17.4% of the total land area. Soil consistency with 'not more than Slightly Firm, Slightly Sticky, Slightly Plastic, hard' represent 51.4% followed by 47.7% of 'fine, very firm, sticky, plastic, very hard' class. The effective soil depth ranges from 0.90-1.22 m represent 49.3% and 45.8% in >1.22 m class in the soils of Bangladesh. Depths are mainly determined by soil consistence.

In case of soil permeability, 56% soils are categorized as moderate (12-305 cm/day) and 34.8% as slow (<12 cm/day). The rate of permeability was determined by soil texture properties. Soils that are poorly drained but where the surface drains early represent 52.7% and imperfectly drained soils 17%. Drainage and permeability are dependable for some crops to be grown in a particular soil type. For example, poorly drained soils suitable for growing boro rice have zero limitation for permeability. Available moisture holding capacity of 100-200 mm represents 45.4% and 200-300 mm 36.5% of the soils. The soil reaction (pH) ranges within 5.5-7.3 available in 61% of soils followed by 23.3% in 7.3-8.4 class. The land factor maps as prepared are presented in Figure 1.

The agro-edaphic suitability map of chickpea and lentil produced based on the steps described in the methodology part are presented in Figures 2 and 3. The extent by different suitability class under chickpea and lentil is presented in Table 7. The table shows agro-edaphic and combined suitable areas in percent of total land area.

Agro-climatic suitability

The agro-climatic suitability map of Rabi Pulses produced based on the averaged minimum temperature of January and December is presented in Figure 4. It is observed from the map that most of the areas are favourable for growing of Rabi pulses which falls under very suitable and suitable category. However, the majority areas in Chittagong region are marginally suitable for growing of Rabi pulses. This is because of high winter temperature which exists during pulse growing season. Low temperatures encountered during Dec-Feb especially towards the north and west of the country, can minimize vegetative growth of both cool and warm season legumes and may delay or reduce podding in crops such as chickpea (Saxena et al. 1988b). A sudden rise in temperature in late Feb in some years severely reduces vegetative growth and pod formation and development of rabi crops, especially of late-sown lentil and chickpea (Rahman et al. 2000). A PET surface generated using average value of January and December is presented in Figure 5. A graph showing the status of temperature, precipitation and PET is presented in Figure 6 which gives an overview of January and December climate of Bangladesh. It was observed from the graph that PET of Dinajpur and Saidpur is less than 2 mm during January and December. The low value of PET gives an indication of excess soil moisture problem for lentil and chickpea in the north of Bangladesh during Rabi growing period. The PET map presented in Figure 5 takes into account of low values and clearly depicts the low PET (< 2mm) in entire Panchagarh and part of Dinajpur, Thakugaon and Nilphamari districts. According to Dr. Johansen low PET causes saturated soil surface conditions (unless vigorous, deep tillage) for Rabi pulses.

Land Suitability Assessment and Classification

The land suitability assessment brings together all the physical constraints and limitations likely to affect chickpea and lentil crop performance. The assessment takes account of all the

attributes of the land (agro-climatic and agro-edaphic in terms of inundation, soil and landform) relevant to the chickpea and lentil being assessed and compares them to the crop's requirements so as to give an easily understood picture of the suitability of the land for production of the chickpea and lentil. The land suitability maps of chickpea and lentil are presented in Figure-7 and Figure-8.

The land suitability assessment as accomplished further refined and modified based on the PET ratings. Accordingly, the land suitability classification is done and final suitability maps of chickpea and lentil pulses are produced (Figure-9 and 10). Afterwards the extent (hectare) under each suitability class is delineated and presented by districts (Table-8a and 8b).

Table 6: Land factors status (% extent in all of Bangladesh)

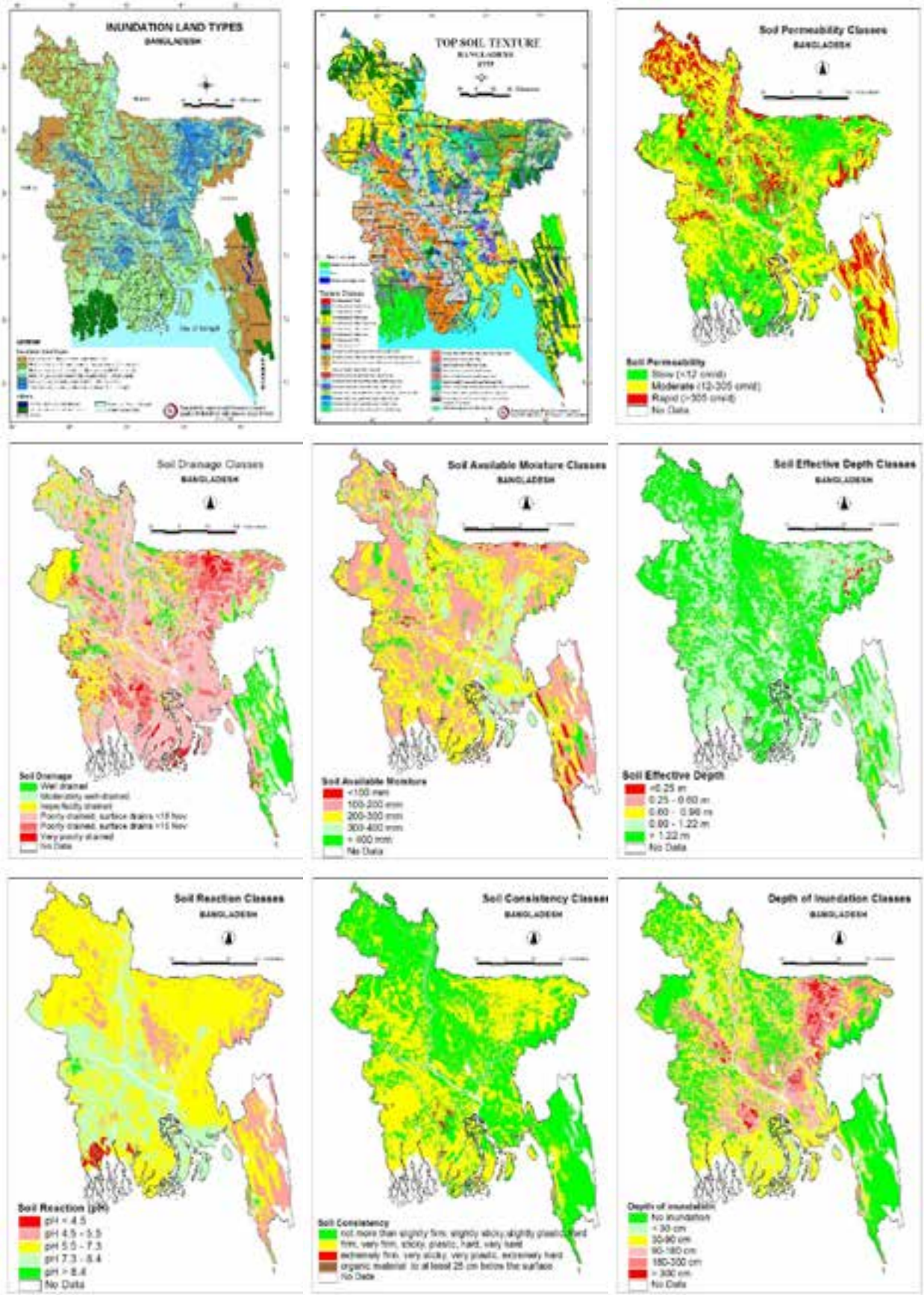
Land Factors	**Class**	**Percent**
Slope	S1 (<3%)	88.6
	S2 (3-8%)	0.1
	S3 (8-16%)	1.2
	S4 (16-30%)	0.0
	S5 (30-45%)	2.3
	S6 (>45%)	7.8
Effective Soil Depth	D1 (<0.25 M)	0.9
	D2 (0.25-0.60 M)	1.8
	D3 (0.60-0.90 M)	2.3
	D4 (0.90-1.22 M)	49.3
	D5 (>1.22 M)	45.8
Available Moisture Holding Capacity	< 100 MM	3.0
	100-200 MM	45.4
	200-300 MM	36.5
	300-400 MM	14.4
	> 400 MM	0.6
Soil Permeability	Slow (<12 cm/day)	34.8
	Moderate (12-305 cm/day)	56.0
	Rapid (>305 cm/day)	9.1
Drainage	Well Drained	11.2
	Moderately Well Drained	5.5
	Imperfectly Drained	17.0
	Poorly Drained but Surface Drains Early	52.7
	Poorly Drained but Surface Drains Late	10.8
	Very Poorly Drained	2.8
Soil Consistency	Not more than Slightly Firm, Slightly Sticky, Slightly Plastic, hard	51.4
	Fine, Very Firm, Sticky, Plastic, Very Hard	47.7
	Extremely Firm, Very Sticky, Very Plastic, Extremely Hard	0.2
	Organic Material to at least 25 cm below the surface	0.7
Soil Reaction	< 4.5	0.5
	4.5-5.5	14.9
	5.5-7.3	61.3
	7.3-8.4	23.3
	> 8.5	0.1
Depth of Inundation	No Flooding	33.5
	Flooding < 0.3 M	9.3
	Flooding 0.30-0.91 M	30.9

Land Factors	Class	Percent
	Flooding 0.91-1.83 M	15.1
	Flooding 1.83-3.05 M	9.5
	Flooding > 3.05 M	1.7
Soil Salinity Status	< 2 MMHOS/cm	91.7
	2-4 MMHOS/cm	3.3
	4-8 MMHOS/cm	4.6
	8-15 MMHOS/cm	0.4
Natural Nutrient Status	Low	16.1
	High	83.9
Hazard Frequency	<= 2%	22.1
	2-6 %	21.9
	6-20%	27.1
	20-50%	16.9
	>= 50%	12.0
Inundation Land Type	Highland	33.7
	Medium Highland 1	9.1
	Medium Highland 2	30.9
	Medium Lowland	15.1
	Lowland	9.5
	Very Lowland	1.7
Topsoil Texture	Sand	0.8
	Loamy Sand	0.3
	Loamy Fine Sand	0.3
	Sandy Loam	4.8
	Fine Sandy Loam	1.8
	Very Fine Sandy Loam	0.1
	Gravely Sandy Clay Loam	0.0
	Sandy Clay Loam	0.2
	Loam	10.5
	Silt	0.2
	Silt Loam	31.3
	Gravely Clay Loam	0.0
	Silty Clay Loam	11.8
	Clay Loam	1.7
	Silty Clay	18.4
	Clay	17.4
	Mucky Clay	0.0
	Muck	0.1
	Peaty Muck	0.1
	Peat	0.1

Table 7: Edaphic and combined (edaphic and climate) suitability of chickpea and lentil

Suitability Class	Edaphic (%)		Combined (%)	
	Chickpea	Lentil	Chickpea	Lentil
VS	9	4	8	3
S	4	16	4	15
MS	47	29	42	27
LS	7	18	9	18
NS	32	32	37	37

Figure 1: Land factor status map



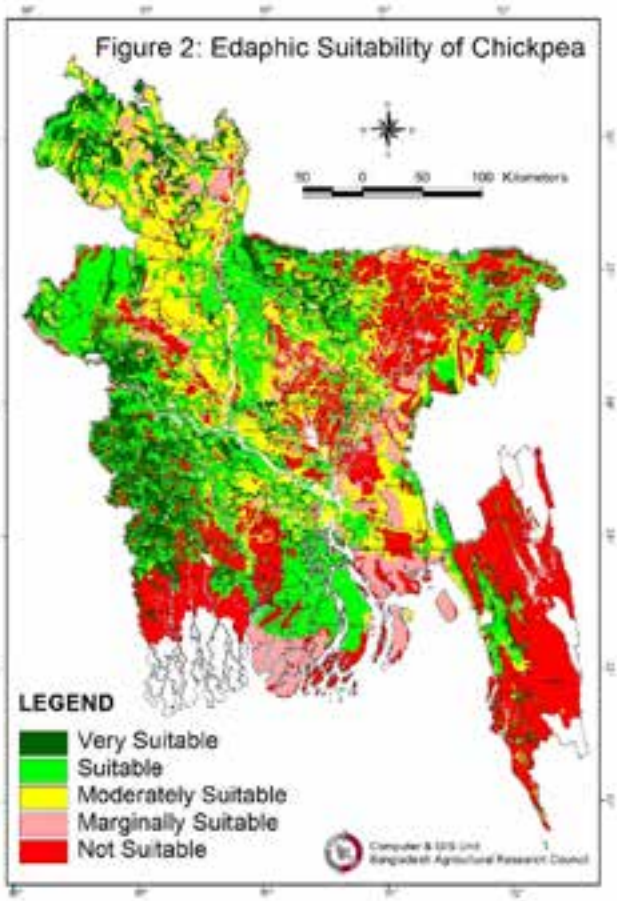


Figure 2: Edaphic Suitability of Chickpea
50 0 50 100 Kilometers
LEGEND
Very Suitable
Suitable
Moderately Suitable
Marginally Suitable
Not Suitable

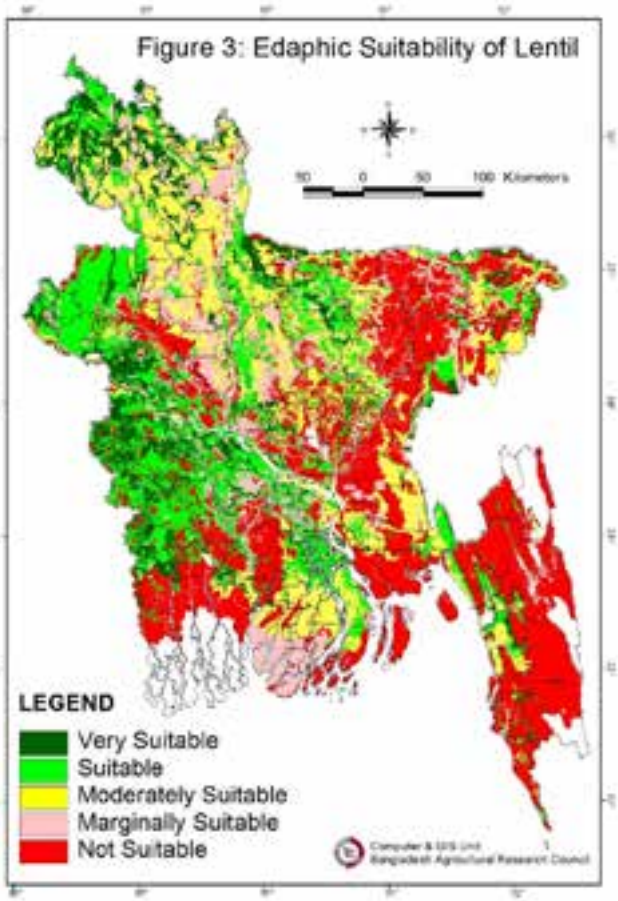


Figure 3: Edaphic Suitability of Lentil
50 0 50 100 Kilometers
LEGEND
Very Suitable
Suitable
Moderately Suitable
Marginally Suitable
Not Suitable

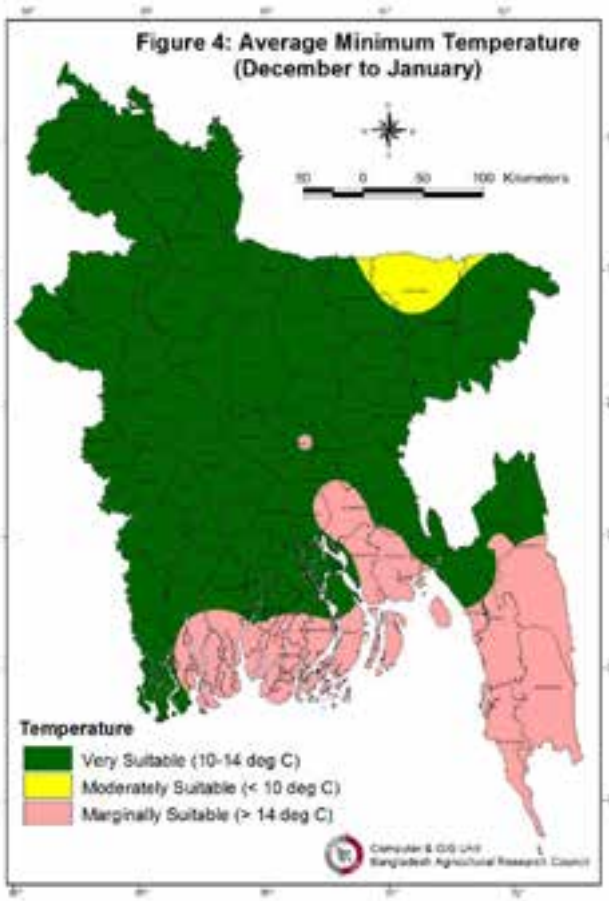


Figure 4: Average Minimum Temperature
(December to January)
50 0 50 100 Kilometers
Temperature
Very Suitable (10-14 deg C)
Moderately Suitable (< 10 deg C)
Marginally Suitable (> 14 deg C)

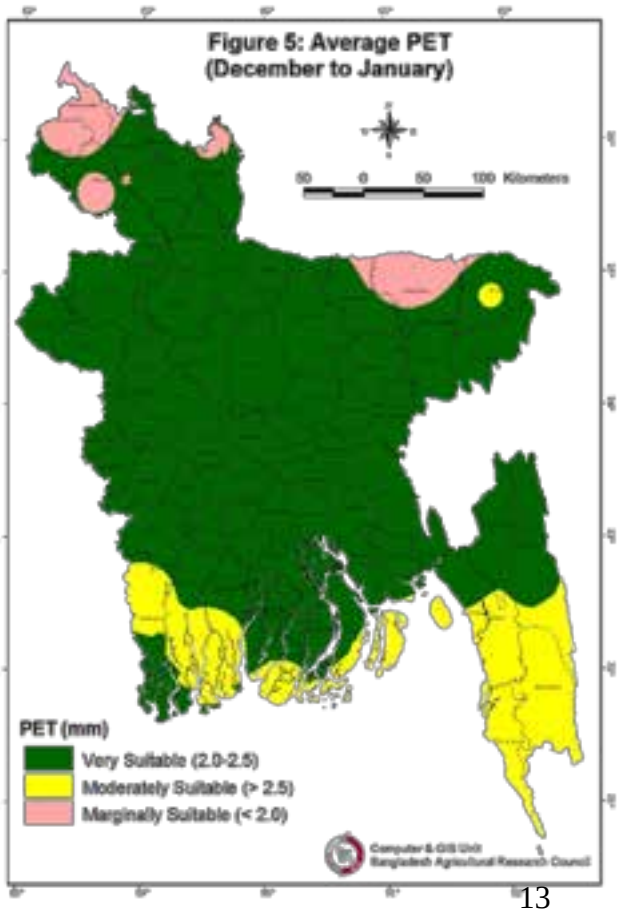
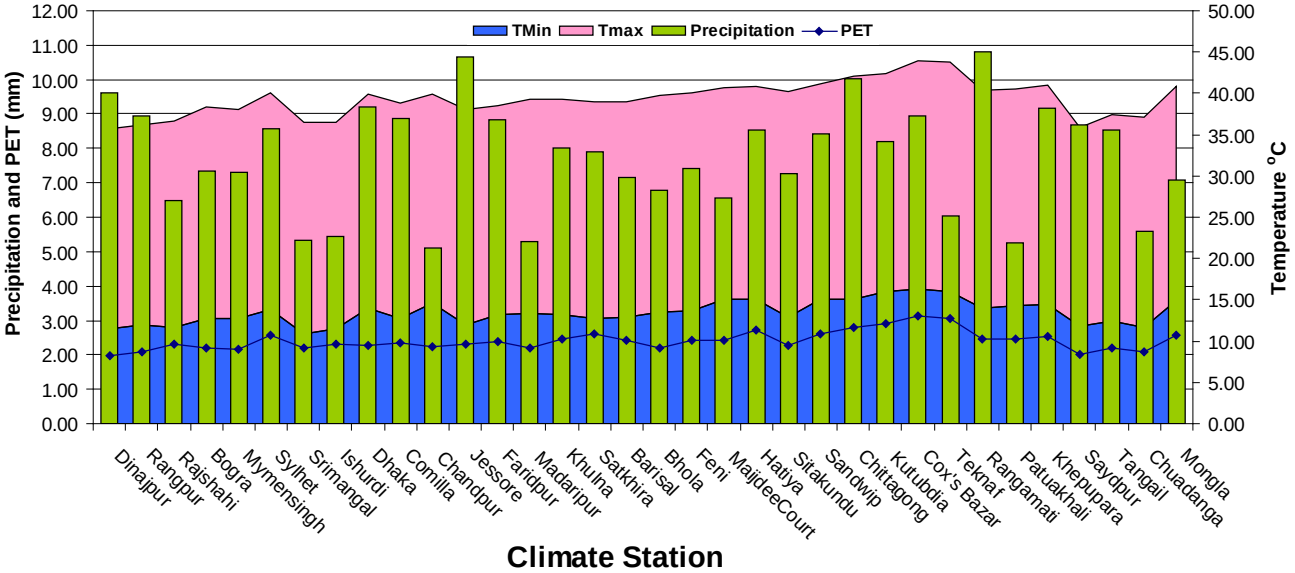
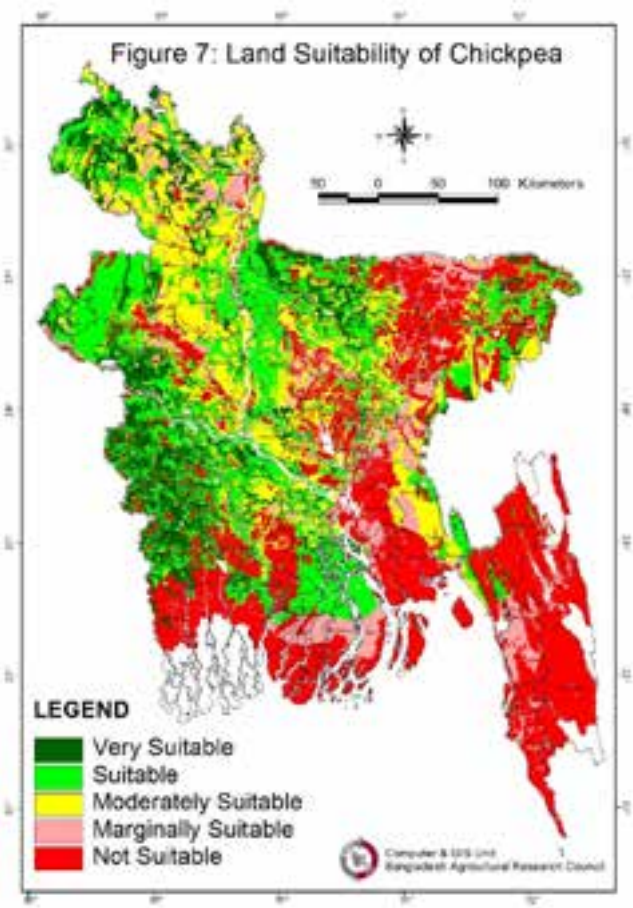
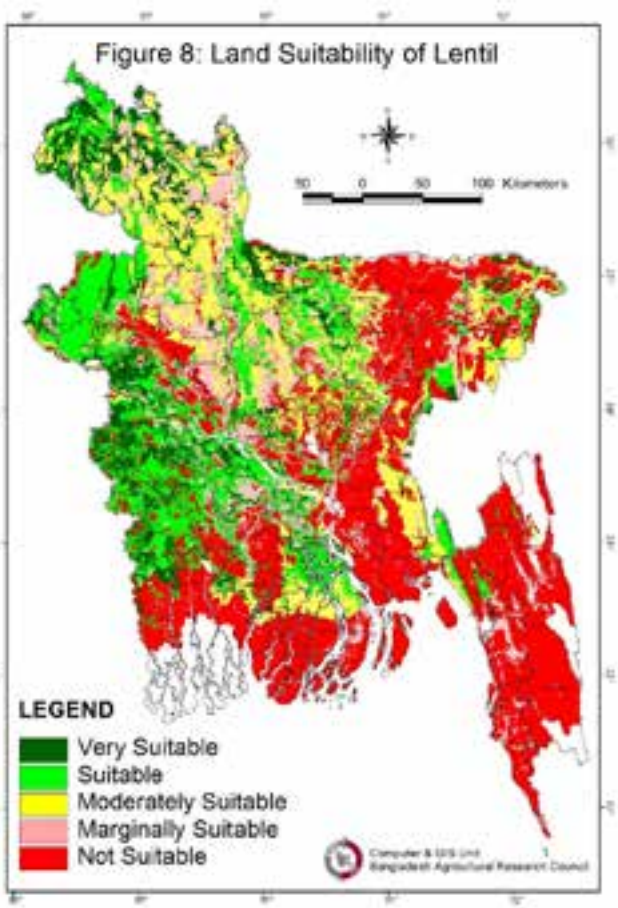


Figure 5: Average PET
(December to January)
50 0 50 100 Kilometers
PET (mm)
Very Suitable (2.0-2.5)
Moderately Suitable (> 2.5)
Marginally Suitable (< 2.0)

Figure-6: Climatic Variation at different regions of Bangladesh
(Average of January and December from 1985-2008)







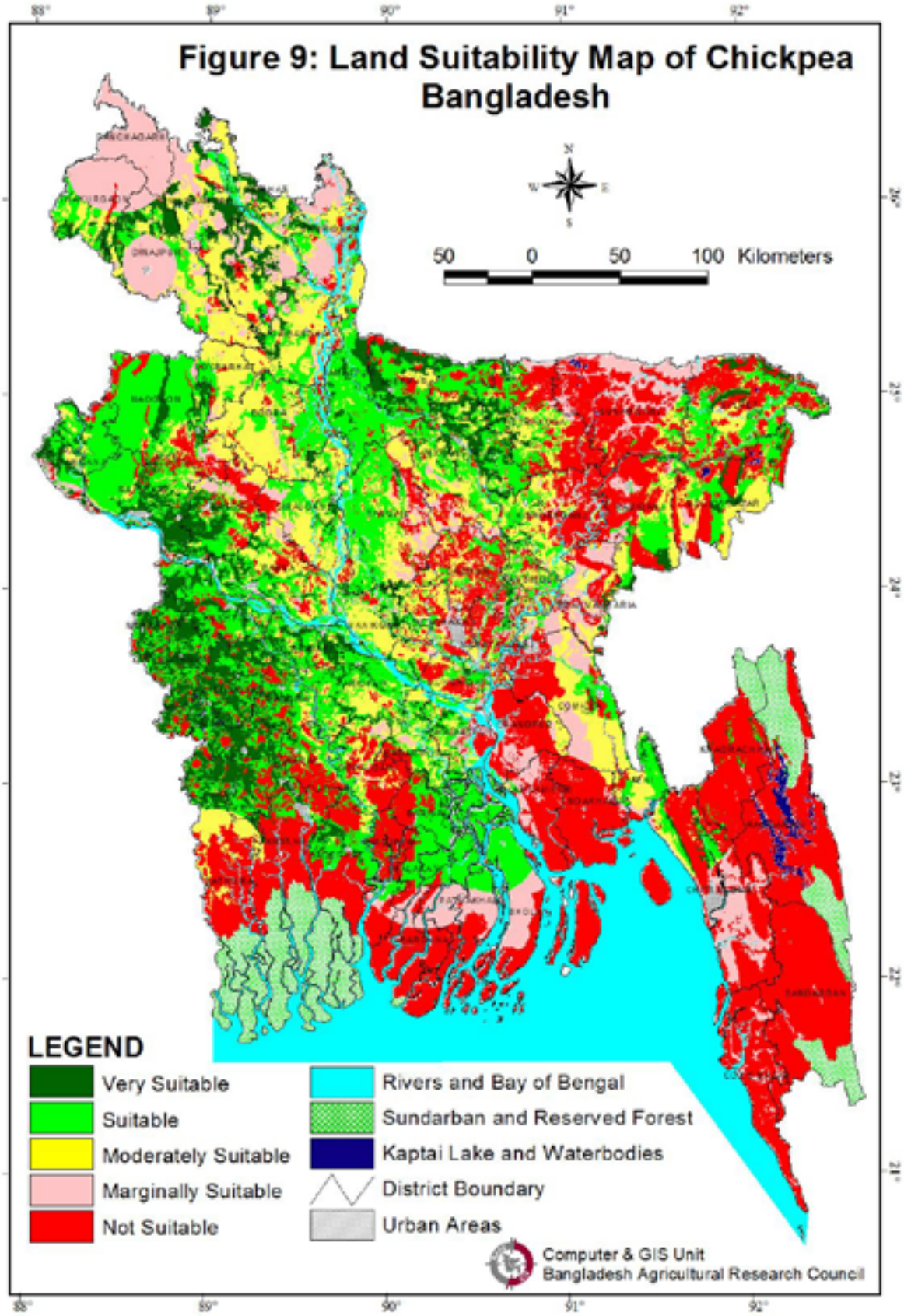


Figure 9: Land Suitability Map of Chickpea
Bangladesh
50 0 50 100 Kilometers
LEGEND
Very Suitable
Suitable
Moderately Suitable
Marginally Suitable
Not Suitable
Rivers and Bay of Bengal
Sundarban and Reserved Forest
Kaptai Lake and Waterbodies
District Boundary
Urban Areas
Computer & GIS Unit
Bangladesh Agricultural Research Council

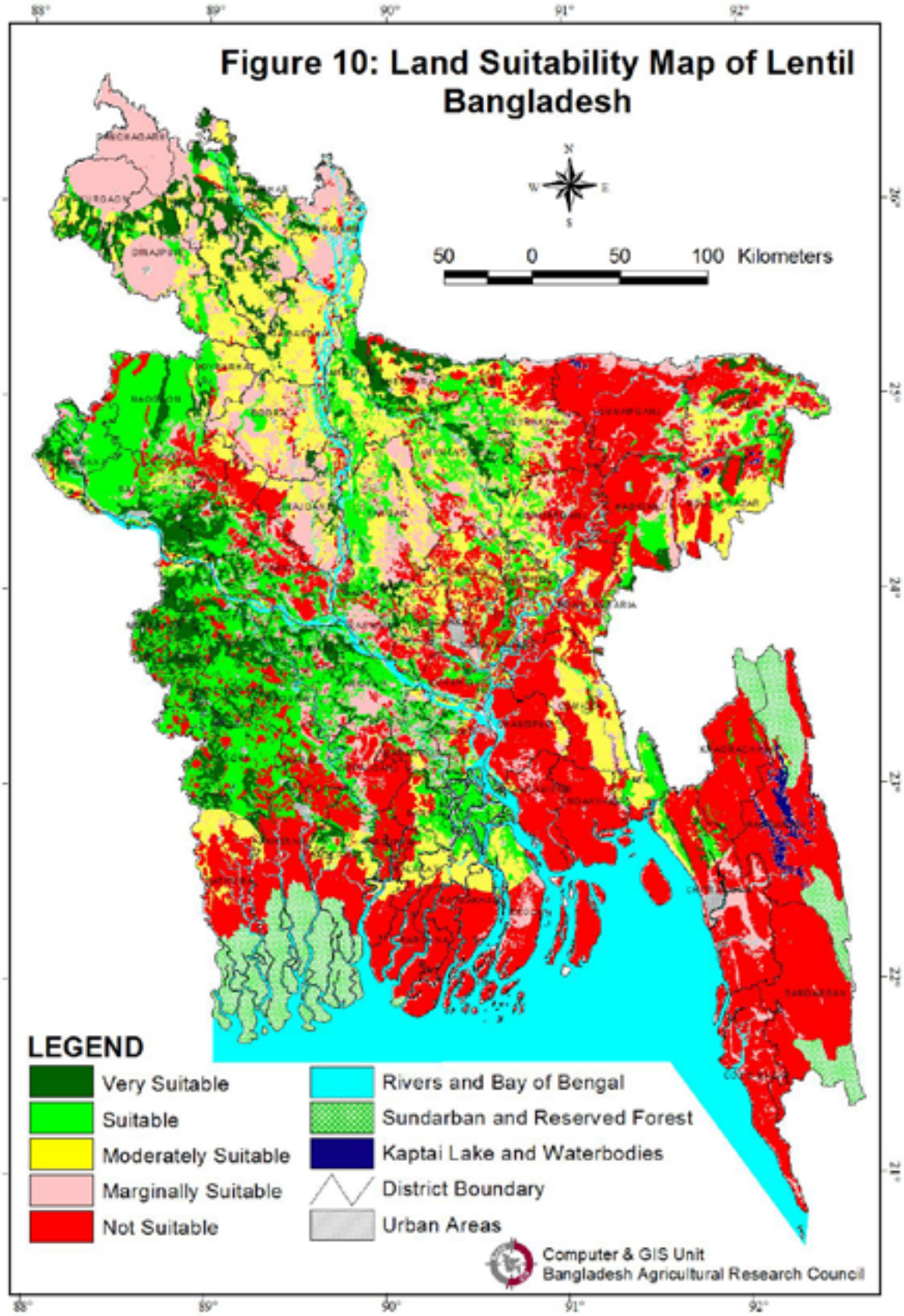


Figure 10: Land Suitability Map of Lentil
Bangladesh
50 0 50 100 Kilometers
LEGEND
Very Suitable
Suitable
Moderately Suitable
Marginally Suitable
Not Suitable
Rivers and Bay of Bengal
Sundarban and Reserved Forest
Kaptai Lake and Waterbodies
District Boundary
Urban Areas
Computer & GIS Unit
Bangladesh Agricultural Research Council

CONCLUSIONS AND RECOMMENDATIONS

The study dealt with constraints analysis of chickpea and lentil cultivation in Bangladesh, and attempted to evaluate their status based on the available information. Subsequently, the land suitability assessment is being carried out to delineate potential suitable areas for production of chickpea and lentil. The land suitability assessment output produced in map and tabular form. The suitability maps generated as output of this study delineates areas for potential suitability for chickpea and lentil crops. The extent (hectare) under each suitability class presented by districts (Table 8a and 8b) indicates the potential for chickpea and lentil crop promotion. The land suitability information provided at the 1:250,000 scale and is therefore suitable for broad planning purposes rather than at the local level. However, this will eventually assist the researchers and policy makers to bring some policy guidelines in the expansion of Rabi pulses cultivation in Bangladesh.

The suitability maps generated as output of this study delineates areas for potential suitability which may not match with the real practice of farmers. In reality, suitability for growing a crop is not only determined by bio-physical potentiality but also by socioeconomic suitability and may be many other factors like marketing, pricing etc. Biotic and socioeconomic constraints that were not considered in this study need to be evaluated and incorporated to get a comprehensive picture on the potential of chickpea and lentil production in Bangladesh. This is because the limiting factors for pulse cultivation may not be primarily agro-climatic and agro-edaphic which were addressed in this study. Although agroecological environment in a particular area may be rated suitable, it may not be economic for farmers to grow pulses in that area if there is a poor market access or other constraints like pest, disease and weed.

It is suggested to conduct a land suitability analysis at a semi-detailed level, at 1:50,000 scale, to further identify the limitations to lentil and chickpea cultivation and provide detailed management options. The upazila level database maintained at BARC could be used in this regard.

Table 8a: Land Suitability for Chickpea by Districts (Hectares)

Division	**District Name**	**VS**	**S**	**MS**	**LS**	**NS**
BARISAL	BARGUNA	0	0	324	0	118665
	BARISAL	10287	0	142137	18	37710
	BHOLA	387	0	54900	0	106812
	JHALAKATI	0	0	50562	0	19710
	PATUAKHALI	0	0	15993	0	180774
	PIROJPUR	1161	0	22689	9	83556
CHITTAGONG	BANDARBAN	0	0	0	70569	289971
	BRAHMANBARIA	2106	207	87291	16308	70281
	CHANDPUR	0	225	21816	3060	126675
	CHITTAGONG	3519	4059	48645	26712	304866
	COMILLA	945	0	185292	12753	99549
	COX'S BAZAR	0	0	0	6255	189108
	FENI	5094	855	56763	0	16263
	KHAGRACHHARI	31689	0	12564	3051	157464
	LAKSHMIPUR	0	0	2988	2169	121896
	NOAKHALI	0	0	6264	99	218592
	RANGAMATI	1746	0	4968	56160	235170

Division	District Name	VS	S	MS	LS	NS
DHAKA	DHAKA	2808	1863	47142	46251	36153
	FARIDPUR	25047	0	159129	45	8262
	GAZIPUR	54	13860	38664	74799	37116
	GOPALGANJ	6030	0	65115	594	79956
	JAMALPUR	21942	2718	148959	2070	20700
	KISHOREGANJ	6309	3798	112455	11961	103815
	MADARIPUR	10773	0	75816	3069	15669
	MANIKGANJ	6984	9	75573	25326	20448
	MUNSHIGANJ	1152	0	34317	16974	30051
	MYMENSINGH	39375	73377	227340	25506	53991
	NARAYANGANJ	1611	477	24795	12474	29187
	NARSINGDI	8280	1233	49878	22266	25578
	NETRAKONA	7929	28683	101493	9198	133785
	RAJBARI	39087	0	57690	18	4878
	SHARIATPUR	8955	0	64719	2178	25137
	SHERPUR	33876	1332	66735	11844	15039
	TANGAIL	432	13707	221481	76617	27810
KHULNA	BAGERHAT	16164	0	59967	0	109755
	CHUADANGA	22005	15120	62694	0	10521
	JESSORE	116829	0	89694	0	40158
	JHENAIDAH	79020	0	95985	0	14310
	KHULNA	10107	0	27621	0	152082
	KUSHTIA	35424	10224	90441	63	18450
	MAGURA	16191	0	75060	0	9774
	MEHERPUR	20979	10071	25983	0	8973
	NARAIL	3654	0	45810	9	44559
	SATKHIRA	11871	0	53811	0	144945
RAJSHAHI	BOGRA	2736	26496	126657	102753	21069
	DINAJPUR	16353	5058	178938	113589	26577
	GAIBANDHA	2907	25668	131112	17487	23454
	JOYPURHAT	72	144	44838	45513	4194
	KURIGRAM	9927	2547	96138	49302	28395
	LALMONIRHAT	5886	2322	67662	20259	10080
	NAOGAON	29448	127800	90918	20448	70038
	NATOR	38367	279	98964	5166	46107
	NAWABGANJ	26946	38124	67284	72	27702
	NILPHAMARI	5364	6435	103203	37035	8793
	PABNA	14553	0	126657	17775	65628
	PANCHAGARH	198	414	558	127080	297
	RAJSHAHI	61389	44172	69687	1404	48510
	RANGPUR	12708	22068	123471	49023	20268
	SIRAJGANJ	12339	4491	142299	22905	41940
	THAKURGAON	13932	1161	37944	120537	1269
SYLHET	HABIGANJ	972	0	148284	1269	101646
	MOULVI BAZAR	23040	1800	148617	22338	63018
	SUNAMGANJ	0	0	44631	94401	217404
	SYLHET	19359	0	131688	10548	165429

Table 8b: Land Suitability for Lentil by Districts (Hectares)

Division	District Name	VS	S	MS	LS	NS
BARISAL	BARGUNA	0	0	189	135	118665
	BARISAL	0	17343	85995	49086	37728
	BHOLA	0	387	54900	0	106812
	JHALAKATI	0	1656	18108	30798	19710
	PATUAKHALI	0	0	15822	171	180774
	PIROJPUR	0	2097	17109	4653	83556
CHITTAGONG	BANDARBAN	0	0	0	124326	236214
	BRAHMANBARIA	0	4644	37251	68544	65754
	CHANDPUR	225	729	8631	21663	120528
	CHITTAGONG	99	21996	29997	50148	285561
	COMILLA	0	1845	84231	103086	109377
	COX'S BAZAR	0	0	0	18990	176373
	FENI	396	7686	47979	9162	13752
	KHAGRACHHARI	21114	15120	8019	3051	157464
	LAKSHMIPUR	0	0	2988	18720	105345
	NOAKHALI	0	18	6030	2601	216306
	RANGAMATI	1332	3654	1728	58419	232911
DHAKA	DHAKA	0	9387	53352	27972	43506
	FARIDPUR	0	28017	98316	57843	8307
	GAZIPUR	0	17325	86094	11574	49500
	GOPALGANJ	0	7146	31869	32724	79956
	JAMALPUR	14004	36036	98127	42336	5886
	KISHOREGANJ	0	19152	60624	43785	114777
	MADARIPUR	0	13842	38376	34398	18711
	MANIKGANJ	0	10674	52848	43785	21033
	MUNSHIGANJ	0	7002	24030	9036	42426
	MYMENSINGH	14886	140841	88947	112221	62694
	NARAYANGANJ	0	3816	19665	10386	34677
	NARSINGDI	0	14733	51876	3798	36828
	NETRAKONA	0	42174	17514	88497	132903
	RAJBARI	0	42120	39798	14913	4842
	SHARIATPUR	0	10782	30231	33039	26937
	SHERPUR	24093	31851	32805	13212	26865
	TANGAIL	0	26613	193887	84510	35037
KHULNA	BAGERHAT	7227	9018	22995	36891	109755
	CHUADANGA	63	43470	55026	1260	10521
	JESSORE	225	116937	80739	8622	40158
	JHENAIDAH	21231	88380	55062	10332	14310
	KHULNA	6480	4275	19746	7227	152082
	KUSHTIA	0	40230	90324	5634	18414
	MAGURA	540	23544	47727	19440	9774
	MEHERPUR	0	24570	32328	135	8973
	NARAIL	0	5382	33138	10953	44559
	SATKHIRA	1665	12069	49086	2862	144945
RAJSHAHI	BOGRA	0	40887	73890	143865	21069
	DINAJPUR	30591	56394	81585	148500	23445
	GAIBANDHA	693	43749	104499	41733	9954
	JOYPURHAT	72	10872	28593	51030	4194

Division	District Name	VS	S	MS	LS	NS
	KURIGRAM	450	16344	77841	77310	14364
	LALMONIRHAT	17829	21834	54531	1935	10080
	NAOGAON	9990	157005	63351	29583	78723
	NATOR	25506	32949	46422	35253	48753
	NAWABGANJ	20781	22662	74250	17640	24795
	NILPHAMARI	29835	30591	75231	16380	8793
	PABNA	36	33561	67923	55503	67590
	PANCHAGARH	108	198	459	127548	234
	RAJSHAHI	41499	53379	61812	20475	47997
	RANGPUR	19872	58923	99063	29412	20268
	SIRAJGANJ	0	44478	38277	92628	48591
	THAKURGAON	5220	14562	41751	112068	1242
SYLHET	HABIGANJ	0	12375	67041	71073	101682
	MOULVI BAZAR	0	51984	129456	14355	63018
	SUNAMGANJ	0	0	13860	59895	282681
	SYLHET	0	24912	106173	30024	165915

VS = Very Suitable : (> 80 % maximum attainable yield, MAT)
S = Suitable : (60 - 80 % MAT)
MS = Moderately suitable : (40 - 60 % MAT)
LS = Marginally suitable : (20 - 40 % MAT)
NS = Not suitable : (< 20 % MAT)

References:

BBS. 2011. Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of Peoples Republic of Bangladesh, Dhaka.

Brammer, H. 1985. Soil-crop suitability classification for Bangladesh (Second Edition, Revised). FAO/UNDP, Agricultural Development Adviser Project (BGD/81/035), Ministry of Agriculture, Dhaka, Bangladesh.

FAOClim-Net. http://geonetwork3.fao.org/climpag/agroclimdb_en.php. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAOSTAT. http://faostat3.fao.org/home/index.html#DOWNLOAD. Food and Agriculture Organization of the United Nations, Rome, Italy.

Hussain S.G., Chowdhury M.A.H., Iqbal, M.A. 2005. Report on updating of edaphic and agroclimatic suitability rules for selected crops of Bangladesh. Submitted to CIMMYT/BARC Bangladesh Country Almanac (BCA) project.

Rahman, M.M., Bakr, M.A., Mia, M.F., Idris, K.M., Gowda, C.L.L., Kumar, J., Deb, U.K., Malek, M.A., and Sobhan, A. 2000. Legumes in Bangladesh Pages 5-34 in Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain – constraints and opportunities (Johansen, C., Duxbury, J.M., Virmani, S.M., Gowda, C.L.L., Pande, S., and Joshi, P.K., eds.) ICRISAT, Patancheru, India; Cornell University, Ithaca, New York, USA.

Saxena, N.P., Johansen, C., Sethi, S.C., Talwar, H.S., and Krishnamurthy, L. 1988b. Improving harvest index of chickpea through incorporation of cold tolerance. International Chickpea Newsletter 7:11-12.

UNDP and FAO. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development, BGD/81/035 Technical Report-2, Agroecological Regions of Bangladesh. United Nations Development Programme and Food and Agriculture Organization of the United Nations, Rome, Italy.