Development of Decision Support System (DSS)
Under SUJALA III Project

Karnataka Watershed Development Project-II (Sujala-III)
Watershed Development Department, Government of Karnataka, Bengaluru

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Chapter 1

Development of Decision Support System (DSS) under Sujala III project

A Key component of SUJALA-III Project is the development of Decision Support System (DSS) along with LRI Digital Library, LRI Portal and Mobile Application for real time dissemination of LRI information and advisories to the farmers, line departments, research institutions and other stakeholders in the state. A DSS is a computerized expert interactive information system developed and integrated in a Geographic Information System environment (GIS) to support decision-making in a particular field or domain. The development of DSS for watershed development/natural resource management depends on the availability of spatial and non-spatial information, like data on soil, water, land use, hydrology, demography, climate, base maps, remote sensing data, and other resource information (Annexure-1) and models, algorithms and rules that can help to infer the outcome.

The objectives of developing DSS in Sujala III project are

- To facilitate the project management in planning, execution and monitoring of various watershed development and other programs in the state
- To integrate Land Resource Inventory, Hydrology, and other database with GIS, MIS and other systems for easy retrieval of information and visualization.
- To support dynamic use of MIS and GIS, monitoring and evaluation, seamless integration of online and offline activities, and dynamic updating of the information.
- To facilitate the convergence of various programs implemented by Watershed, Agriculture, Horticulture, Forestry, Animal Husbandry, Rural Development and other line departments at the watershed/village level in the state.
- To develop criteria, algorithms and models, knowledge base and expert systems needed to help the decision makers to access relevant information from a combination of raw data, documents, and personal knowledge, or models to identify and solve problems and make appropriate decisions as and when needed.

The Decision Support System is developed primarily to serve the needs of planning, implementation and monitoring of watershed development programs in the state by Watershed Development Department, Departments of Horticulture, Agriculture, Animal Husbandry, and other line departments, LRI project partners, and other stakeholders. The DSS development is based on the integration of data generated by LRI partners and compiled from other sources (Annexure 1) with criteria, models and algorithms already available or developed under this project. It is critical for the successful implementation of various watershed programs, other line department schemes and for empowering farmers and other stakeholders in the state. As a part of Sujala III Project, nine Decision Support Systems are developed in the first phase to facilitate the departments to take up key interventions and to provide advisories to the farmers and other stakeholders at the grassroots level as indicated below.

Table 1.1 DSS modules developed as part of Sujala III project

S.No	Decision Support System	Primary Responsibility
Group 1 (Soil & Water conservation plan, Crop selection, Land Capability Classification and Nutrient management)		
1	DSS for **Soil & Water conservation plan**-to identify the type of structures, their design and estimate, for both arable and non-arable lands/areas	WDD, NBSS&LUP, ICRISAT, SAU's
2	DSS for **Crop selection** (Based on physical suitability and cost benefit ratio)	NBSS&LUP SAUs
3	DSS for delineating prime farmlands/arable and non-arable lands based on **Land Capability Classification**	NBSS&LUP, SAUs
4	DSS on crop based **Nutrient Management** and **Soil Health**	NBSS&LUP, SAUs
Group 2 (Surface Runoff, Size and location of Farm Ponds and Check Dams, Crop water requirement, Soil Water balance and Water budgeting)		
5	DSS for estimating **Surface runoff** at farm/MWS/SWS levels	ICRISAT, SAUs, IISc and Domain experts
6	DSS for designing the **Size and location of Farm ponds and Check dams** based on runoff model	SAUs and Domain experts
7	DSS for estimating the **Crop water requirement** at MWS/SWS levels based on the existing land use or crops that are planned to be taken up for cultivation	ICRISAT, SAUs, IISc and Domain experts
8	DSS for estimating **Soil Water balance** at MWS or higher levels, considering the RF, crop requirement, Runoff, evaporation and other losses, soil moisture and ground water.	ICRISAT, SAUs, IISc and Domain experts
9	DSS for **Water budgeting** taking into consideration the needs of various uses/users at MWS/ Village level- crop needs, human needs, livestock needs etc.	ICRISAT, SAUs, IISc and Domain experts

The DSS on Soil and Water conservation helps to identify appropriate conservation structures for the arable and non-arable lands based on site-specific parcel level information generated through Land Resource Inventorisation and available to the users in the form of LRI and Hydrology Reports and Atlases. The DSS on Crop suitability assessment helps the planner to prepare a matrix of suitable and not suitable crops for a given area and the farmer to choose the best suited crop for the farm. The DSS on Nutrient management enables the farmer to choose the type, quantity and time of application of fertilisers to the selected crop under cultivation based on the nutrient status of the soil and the planner to identify the extent of deficient/sufficient areas for taking up appropriate interventions. The DSS on Land Capability, Runoff, Farm Ponds and Check Dams, Crop water requirement, Soil moisture and

water balance and Water budgeting facilitate the departments to take up key interventions and to provide advisories to the farmers and other stakeholders at different levels.

The development of the nine Decision Support Systems is based on the criteria, type of models, algorithms and state of knowledge available at present in the respective domains. The output from the model/DSS may or may not reflect the existing field situations due to various reasons. Hence the outputs generated by using the DSS needs to be verified/validated in the field and recalibrated/modified wherever necessary with inputs/feedbacks received from the stakeholders before they are finally deployed in the Portal.

The Functional Requirements Specifications (FRS) for the Nine Decision Support Systems (DSS) developed in the first phase under Sujala III project is elaborated in the following Chapters.

Chapter 2

DSS for Soil and Water Conservation Plan for Arable and Non-arable areas

The sustainability of soil and water resources, particularly of the vast rainfed tracts of the state, depends on the effectiveness of the conservation measures planned and executed at the field level. The availability of cadastral level soil, water, weather, hydrology, land use, cropping pattern etc., generated through LRI from Sujala III project helps to design appropriate conservation measures required at the field/watershed level. The conservation plan is prepared by matching the site-specific constraints and potentials of the area with different type of conservation measures and selecting the appropriate one based on the criteria available. The criteria for different type of structures is generated by various agencies (SAU's, WDD, ICAR, ICRISAT and others) over a period through field trials at different locations. The development of DSS for Soil and Water Conservation based on the above criteria enables the user/department to generate the conservation map of any watershed including the budget requirement and inter bund conservation practices to be followed in a fraction of a time. This chapter elaborates the criteria used for the development of the DSS, look up table for deciding the type of structures, cost norms followed, flow charts and expected outputs (maps, tables etc.) from the DSS.

The major interventions followed for soil and water conservation at the field level are bunding, terracing and trenching. The criteria for selecting the type of treatment to be used depends on the amount of rainfall, type of landform, soils, land use etc. The treatment for arable lands will be different from the non-arable lands. Similarly, the treatment for black soils will be different than the red and lateritic soils observed in the state. Accordingly, the criteria and their range or limits to be used for arable-black soils, arable red and lateritic soils, and non-arable areas occurring in the watershed area is finalized and the same is presented below. The sequence of activities involved in the selection of different structures and preparation of Soil and Water conservation plan for a given watershed is elaborated in the Implementation Manual for Sujala III project (WDD, 2016).

Table 2.1 Master Land Slope classes as per LRI and derived land slope classes used for decision criteria.

Master table for Land slope			Derived slope class table of land slope for conservation plan		
Slope Class	Slope class MID		Arable-Black soils	Arable-Red/lateritic soil	Non arable soil
<1	1		<1	<1	<5
1-3	2		1-3	1-3	>5 (5-10)[1]
3-5	3		3-5	3-5	(10-25)
5-10	4		5-10	5-10	
10-15	5			10-15	
15-25				15-25	

25-33				25-33	
>33				>33	

Note: As per the Technical Manual for Integrated Watershed Development of Institute of Agricultural Technologists, Bangalore Arable land treatments for Black soils are advocated for 1 to 5% Land slope. [1] 5-10 and 10-15 slope classes for non-arable lands are not provided in the criteria table at present, which needs to be developed.

Table 2.2 Master soil depth classes as per LRI and derived soil depth classes used for decision criteria.

Master table for soil depth			Derived depth table of soil depth for conservation plan		
Depth Class	Depth class MID		Arable-Black soils	Arable-Red/lateritic soil	Non arable soil
<25	1		<50	25-50	<25
25-50	2		50-100	>50	>25
50-75	3		>100		
75-100	4				
100-150	5				
>150	6				

Table 2.3 Master soil texture classes as per LRI and derived soil texture classes used for decision criteria.

Master table for soil texture			Derived table of soil texture for conservation plan		
Texture Class	Texture class MID		Texture class	Texture class DID	MID
Sand	1		Loam	1	1 to 7
Loamy sand	2		Clay	2	8 to 12
Sandy loam	3				
Loam	4			3	
Silt	5				
Silt Loam	6				
Sandy clay loam	7				
Clay loam	8				
Silty clay loam	9				
Sandy clay	10				
Silty clay	11				
Clay	12				

Note: For loamy sand and sand, there is no separate conservation treatment available, accordingly they are included as part of the loamy textural class at present.

Table 2.4 Master gravel classes as per LRI and derived gravel classes used for decision criteria.

Master table for Gravel			Derived table of gravel for conservation plan		
Gravel Class	Gravel class MID		Gravel class	Gravel class DID	MID
<15	1		<35	1	1 and 2
15-35	2		>35	2	3 and 4
35-60	3				
>60	4				

Table 2.5 Master rainfall classes as per LRI and derived rainfall classes used for decision criteria.

Master table for rainfall			Derived table of rainfall for conservation plan		
Rainfall Class	Rainfall class MID		Arable-black soil	Arable-red / lateritic soil	Non arable
<500	1		<750	<750	<750
500-800	2		750-950	750-950	750-950
800-1000	3		>950	>950	>950
1000-1500	4				
>1500	5				

Note: As per the Technical Manual for Integrated Watershed Development of Institute of Agricultural Technologists, Bangalore Arable land treatments like Contour bunds/Trench cum bunds are suggested for regions receiving rainfall up to 750mm.; Graded bunds for regions receiving 750-950 mm rainfall and also Black soils with Infiltration rate <6mm/hr (Deep black soils).

Table 2.6 Criteria for deciding conservation treatment for **Arable Land-Black soil.**

S. No.	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<1	<50	Loam	Clay	<35%	<750	Contour bunding/TCB[1]
2	<1	<50	Loam	Clay	<35%	750-950	Graded bund
3	1 to 3	<50	Loam	Clay	<35%	<750	Contour bunding/TCB
4	1 to 3	<50	Loam	Clay	<35%	750-950	Graded bund
5	3 to 5	<50	Loam	Clay	<35%	<750	Contour bunding/TCB
6	3 to5	<50	Loam	Clay	<35%	750-950	Graded bund
7	5 to 10	<50	Loam	Clay	<35%	<750	Graded bund
8	5 to 10	<50	Loam	Clay	<35%	750-950	Graded bund

9	<1	50-100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
10	<1	50-100	Loam	Clay	<35%	750-950	Graded bund
11	1 to 3	50-100	Loam	Clay	<35%	<750	Contour bunding[2] /TCB
12	1 to 3	50-100	Loam	Clay	<35%	750-950	Graded bund
13	3 to 5	50-100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
14	3 to5	50-100	Loam	Clay	<35%	750-950	Graded bund
15	5 to 10	50-100	Loam	Clay	<35%	<750	Graded bund
16	5 to 10	50-100	Loam	Clay	<35%	750-950	Graded bund
17	<1	>100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
18	<1	>100	Loam	Clay	<35%	750-950	Graded bund
19	1 to 3	>100	Loam	Clay	<35%	<750	Contour bunding[2] /TCB
20	1 to 3	>100	Loam	Clay	<35%	750-950	Graded bund
21	3 to 5	>100	Loam	Clay	<35%	<750	Contour bunding[2]/TCB
22	3 to5	>100	Loam	Clay	<35%	750-950	Graded bund
23	5 to 10	>100	Loam	Clay	<35%	<750	Graded bund
24	5 to 10	>100	Loam	Clay	<35%	750-950	Graded bund
25	<1	<50	Clay	Clay	<35%	<750	Graded bund
26	<1	<50	Clay	Clay	<35%	750-950	Graded bund
27	1 to 3	<50	Clay	Clay	<35%	<750	Graded bund
28	1 to 3	<50	Clay	Clay	<35%	750-950	Graded bund
29	3 to 5	<50	Clay	Clay	<35%	<750	Graded bund
30	3 to5	<50	Clay	Clay	<35%	750-950	Graded bund
31	5 to 10	<50	Clay	Clay	<35%	<750	Graded bund
32	5 to 10	<50	Clay	Clay	<35%	750-950	Graded bund
33	<1	50 to 100	Clay	Clay	<35%	<750	Graded bund
34	<1	50 to 100	Clay	Clay	<35%	750-950	Graded bund
35	1 to 3	50 to 100	Clay	Clay	<35%	<750	Graded bund
36	1 to 3	50 to 100	Clay	Clay	<35%	750-950	Graded bund
37	3 to 5	50 to 100	Clay	Clay	<35%	<750	Graded bund
38	3 to5	50 to 100	Clay	Clay	<35%	750-950	Graded bund
39	5 to 10	50 to 100	Clay	Clay	<35%	<750	Graded bund
40	5 to 10	50 to 100	Clay	Clay	<35%	750-950	Graded bund
41	<1	>100	Clay	Clay	<35%	<750	Graded bund
42	<1	>100	Clay	Clay	<35%	750-950	Graded bund
43	1 to 3	>100	Clay	Clay	<35%	<750	Graded bund
44	1 to 3	>100	Clay	Clay	<35%	750-950	Graded bund

45	3 to 5	>100	Clay	Clay	<35%	<750	Graded bund
46	3 to5	>100	Clay	Clay	<35%	750-950	Graded bund
47	5 to 10	>100	Clay	Clay	<35%	<750	Graded bund
48	5 to 10	>100	Clay	Clay	<35%	750-950	Graded bund
49	<1	<50	Loam	Clay	>35%	<750	Contour bund/TCB
50	<1	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
51	1 to 3	<50	Loam	Clay	>35%	<750	Contour bund/TCB
52	1 to 3	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
53	3 to 5	<50	Loam	Clay	>35%	<750	Contour bund/TCB
54	3 to5	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
55	5 to 10	<50	Loam	Clay	>35%	<750	Contour bund/TCB
56	5 to 10	<50	Loam	Clay	>35%	750-950	Contour bund/TCB
57	<1	50-100	Loam	Clay	>35%	<750	Contour bund^2/TCB
58	<1	50-100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
59	1 to 3	50-100	Loam	Clay	>35%	<750	Contour bund^2/TCB
60	1 to 3	50-100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
61	3 to 5	50-100	Loam	Clay	>35%	<750	Contour bund^2/TCB
62	3 to5	50-100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
63	5 to 10	50-100	Loam	Clay	>35%	<750	Contour bund^2/TCB
64	5 to 10	50-100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
65	<1	>100	Loam	Clay	>35%	<750	Contour bund^2/TCB
66	<1	>100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
67	1 to 3	>100	Loam	Clay	>35%	<750	Contour bund^2/TCB
68	1 to 3	>100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
69	3 to 5	>100	Loam	Clay	>35%	<750	Contour bund^2/TCB
70	3 to5	>100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
71	5 to 10	>100	Loam	Clay	>35%	<750	Contour bund^2/TCB

72	5 to 10	>100	Loam	Clay	>35%	750-950	Contour bund^2/TCB
73	<1	<50	Clay	Clay	>35%	<750	Contour bund/TCB
74	<1	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
75	1 to 3	<50	Clay	Clay	>35%	<750	Contour bund/TCB
76	1 to 3	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
77	3 to 5	<50	Clay	Clay	>35%	<750	Contour bund/TCB
78	3 to5	<50	Clay	Clay	>35%	750-950	Contour bund/TCB
79	5 to 10	<50	Clay	Clay	>35%	<750	Contour bund/TCB
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81	<1	50 to 100	Clay	Clay	>35%	<750	Contour bund^2/TCB
82	<1	50 to 100	Clay	Clay	>35%	750-950	Contour bund^2/TCB
83	1 to 3	50 to 100	Clay	Clay	>35%	<750	Contour bund^2/TCB
84	1 to 3	50 to 100	Clay	Clay	>35%	750-950	Contour bund^2/TCB
85	3 to 5	50 to 100	Clay	Clay	>35%	<750	Contour bund/^{2}TCB
86	3 to5	50 to 100	Clay	Clay	>35%	750-950	Contour bund^2/TCB
87	5 to 10	50 to 100	Clay	Clay	>35%	<750	Contour bund^2/TCB
88	5 to 10	50 to 100	Clay	Clay	>35%	750-950	Contour bund^2/TCB
89	<1	>100	Clay	Clay	>35%	<750	Graded bunds
90	<1	>100	Clay	Clay	>35%	750-950	Graded bunds
91	1 to 3	>100	Clay	Clay	>35%	<750	Graded bunds
92	1 to 3	>100	Clay	Clay	>35%	750-950	Graded bunds
93	3 to 5	>100	Clay	Clay	>35%	<750	Graded bunds
94	3 to5	>100	Clay	Clay	>35%	750-950	Graded bunds
95	5 to 10	>100	Clay	Clay	>35%	<750	Graded bunds
96	5 to 10	>100	Clay	Clay	>35%	750-950	Graded bunds
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101	3 to 5	<50	Loam	Loam	<35%	<750	Contour bunding/TCB
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160	5 to 10	50-100	Loam	Loam	>35%	750-950	Contour bund/TCB
161	<1	>100	Loam	Loam	>35%	<750	Contour bund^2/TCB
162	<1	>100	Loam	Loam	>35%	750-950	Contour bund^2/TCB
163	1 to 3	>100	Loam	Loam	>35%	<750	Contour bund^2/TCB
164	1 to 3	>100	Loam	Loam	>35%	750-950	Contour bund^2/TCB
165	3 to 5	>100	Loam	Loam	>35%	<750	Contour bund^2/TCB
166	3 to5	>100	Loam	Loam	>35%	750-950	Contour bund^2/TCB
167	5 to 10	>100	Loam	Loam	>35%	<750	Contour bund/TCB
168	5 to 10	>100	Loam	Loam	>35%	750-950	Contour bund/TCB

169	<1	<50	Clay	Loam	>35%	<750	Contour bund/TCB
170	<1	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
171	1 to 3	<50	Clay	Loam	>35%	<750	Contour bund/TCB
172	1 to 3	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
173	3 to 5	<50	Clay	Loam	>35%	<750	Contour bund/TCB
174	3 to5	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
175	5 to 10	<50	Clay	Loam	>35%	<750	Contour bund/TCB
176	5 to 10	<50	Clay	Loam	>35%	750-950	Contour bund/TCB
177	<1	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
178	<1	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
179	1 to 3	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
180	1 to 3	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
181	3 to 5	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
182	3 to5	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
183	5 to 10	50 to 100	Clay	Loam	>35%	<750	Contour bund/TCB
184	5 to 10	50 to 100	Clay	Loam	>35%	750-950	Contour bund/TCB
185	<1	>100	Clay	Loam	>35%	<750	Contour bund/TCB
186	<1	>100	Clay	Loam	>35%	750-950	Contour bund/TCB
187	1 to 3	>100	Clay	Loam	>35%	<750	Graded bunds
188	1 to 3	>100	Clay	Loam	>35%	750-950	Graded bunds
189	3 to 5	>100	Clay	Loam	>35%	<750	. Graded bunds
190	3 to5	>100	Clay	Loam	>35%	750-950	. Graded bunds
191	5 to 10	>100	Clay	Loam	>35%	<750	Graded bunds
192	5 to 10	>100	Clay	Loam	>35%	750-950	Graded bunds

Note: [1] As per the criteria, the recommended conservation measure is contour bunding, but in practice, TCB is commonly adopted by the department in the field. However, the cost of bunding for both remains the same.

[2] Zingg Terracing: If the surface soil texture is loamy or lighter and the depth is more than 50 cm, then along with contour bunding Zingg Terracing may be recommended in black soils upto 5 per cent land slope.

Normally in black soils terracing is not a common practice. But if the slope exceeds 5 per cent in black soils terracing is preferred instead of graded bunds. In red and lateritic soils, terracing is recommended if the slope exceeds 10 per cent.

Table 2.7 Criteria for deciding conservation treatment for **Arable-red and lateritic soils**

S. No.	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<1	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
2	<1	25-50	Loam	Clay	<35%	750-950	Graded bund
3	1 to 3	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
4	1 to 3	25-50	Loam	Clay	<35%	750-950	Graded bund
5	3 to 5	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
6	3 to 5	25-50	Loam	Clay	<35%	750-950	Graded bund
7	5 to 10	25-50	Loam	Clay	<35%	<750	Contour bunding/TCB
8	5 to 10	25-50	Loam	Clay	<35%	750-950	Graded bund
9	10 to 15	25-50	Loam	Clay	<35%	<950	Terracing (Sloping outward/Level terrace)
10	10 to 15	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
11	15 to 25	25-50	Loam	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
12	15 to 25	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
13	25 to 33	25-50	Loam	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
14	25 to 33	25-50	Loam	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
15	>33	25-50	Loam	Clay	<35%	<=950	Plantation terrace
16	>33	25-50	Loam	Clay	<35%	>950	Peurotorican terrace
17	<1	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
18	<1	25-50	Loam	Loam	<35%	750-950	Graded bund
19	1 to 3	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
20	1 to 3	25-50	Loam	Loam	<35%	750-950	Graded bund
21	3 to 5	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
22	3 to 5	25-50	Loam	Loam	<35%	750-950	Graded bund
23	5 to 10	25-50	Loam	Loam	<35%	<=750	Contour bunding/TCB
24	5 to 10	25-50	Loam	Loam	<35%	750-950	Graded bund
25	10 to 15	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
26	10 to 15	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/ Level terrace)
27	15 to 25	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
28	15 to 25	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)

29	25 to 33	25-50	Loam	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
30	25 to 33	25-50	Loam	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
31	>33	25-50	Loam	Loam	<35%	<=950	Plantation terrace
32	>33	25-50	Loam	Loam	<35%	>950	Peurotorican terrace
33	<1	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
34	<1	25-50	Clay	Clay	<35%	750-950	Graded bund
35	1 to 3	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
36	1 to 3	25-50	Clay	Clay	<35%	750-950	Graded bund
37	3 to 5	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
38	3 to 5	25-50	Clay	Clay	<35%	750-950	Graded bund
39	5 to 10	25-50	Clay	Clay	<35%	<750	Contour bunding/TCB
40	5 to 10	25-50	Clay	Clay	<35%	750-950	Graded bund
41	10 to 15	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
42	10 to 15	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
43	15 to 25	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
44	15 to 25	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
45	25 to 33	25-50	Clay	Clay	<35%	<=950	Terracing (Sloping outward/Level terrace)
46	25 to 33	25-50	Clay	Clay	<35%	>950	Terracing (Sloping inwards/Level terrace)
47	>33	25-50	Clay	Clay	<35%	<=950	Plantation terrace
48	>33	25-50	Clay	Clay	<35%	>950	Peurotorican terrace
49	<1	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
50	<1	25-50	Clay	Loam	<35%	>950	Graded bund
51	1 to 3	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
52	1 to 3	25-50	Clay	Loam	<35%	>950	Graded bund
53	3 to 5	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
54	3 to 5	25-50	Clay	Loam	<35%	>950	Graded bund
55	5 to 10	25-50	Clay	Loam	<35%	<=950	Contour bunding/TCB
56	5 to 10	25-50	Clay	Loam	<35%	>950	Graded bund
57	10 to 15	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
58	10 to 15	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
59	15 to 25	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)

60	15 to 25	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
61	25 to 33	25-50	Clay	Loam	<35%	<=950	Terracing (Sloping outward/Level terrace)
62	25 to 33	25-50	Clay	Loam	<35%	>950	Terracing (Sloping inwards/Level terrace)
63	>33	25-50	Clay	Loam	<35%	<=950	Plantation terrace
64	>33	25-50	Clay	Loam	<35%	>950	Peurotorican terrace
65	<1	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
66	<1	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
67	1 to 3	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
68	1 to 3	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
69	3 to 5	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
70	3 to 5	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
71	5 to 10	25-50	Loam	Clay	>35%	750-950	Contour bunding/TCB
72	5 to 10	25-50	Loam	Clay	>35%	>950	Contour bunding/TCB
73	10 to 15	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
74	10 to 15	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
75	15 to 25	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
76	15 to 25	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
77	25 to 33	25-50	Loam	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
78	25 to 33	25-50	Loam	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
79	>33	25-50	Loam	Clay	>35%	750-950	Plantation terrace
80	>33	25-50	Loam	Clay	>35%	>950	Peurotorican terrace
81	<1	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
82	<1	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
83	1 to 3	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
84	1 to 3	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
85	3 to 5	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
86	3 to 5	25-50	Loam	Loam	>35%	>950	Contour bunding/TCB
87	5 to 10	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
88	5 to 10	25-50	Loam	Loam	>35%	750-950	Contour bunding/TCB
89	10 to 15	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
90	10 to 15	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)

91	15 to 25	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
92	15 to 25	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)
93	25 to 33	25-50	Loam	Loam	>35%	>950	Terracing (Sloping outward/Level terrace)
94	25 to 33	25-50	Loam	Loam	>35%	750-950	Terracing (Sloping inwards/Level terrace)
95	>33	25-50	Loam	Loam	>35%	>950	Plantation terrace
96	>33	25-50	Loam	Loam	>35%	>950	Peurotorican terrace
97	<1	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
98	<1	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
99	1 to 3	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
100	1 to 3	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
101	3 to 5	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
102	3 to 5	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
103	5 to 10	25-50	Clay	Clay	>35%	750-950	Contour bunding/TCB
104	5 to 10	25-50	Clay	Clay	>35%	>950	Contour bunding/TCB
105	10 to 15	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
106	10 to 15	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
107	15 to 25	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
108	15 to 25	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
109	25 to 33	25-50	Clay	Clay	>35%	750-950	Terracing (Sloping outward/Level terrace)
110	25 to 33	25-50	Clay	Clay	>35%	>950	Terracing (Sloping inwards/Level terrace)
111	>33	25-50	Clay	Clay	>35%	>950	Plantation terrace
112	>33	25-50	Clay	Clay	>35%	>950	Peurotorican terrace
113	<1	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
114	<1	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
115	1 to 3	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
116	1 to 3	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
117	3 to 5	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
118	3 to 5	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
119	5 to 10	25-50	Clay	Loam	>35%	750-950	Contour bunding/TCB
120	5 to 10	25-50	Clay	Loam	>35%	>950	Contour bunding/TCB
121	10 to 15	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)

122	10 to 15	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
123	15 to 25	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)
124	15 to 25	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
125	25 to 33	25-50	Clay	Loam	>35%	750-950	Terracing (Sloping outward/Level terrace)
126	25 to 33	25-50	Clay	Loam	>35%	>950	Terracing (Sloping inwards/Level terrace)
127	>33	25-50	Clay	Loam	>35%	750-950	Plantation terrace
128	>33	25-50	Clay	Loam	>35%	>950	Peurotorican terrace

Note: [1]As per the criteria, the recommended conservation measure is contour bunding, but in practice, TCB is commonly adopted by the department in the field. However, the cost of bunding for both remains the same.

Table 2.8 Decision criteria for selecting treatment for **Non-arable lands**

S. No.	Slope	Depth	Texture		Gravel	Rainfall	Treatment
			Surface	Subsurface			
1	<5	<25	Loam	Clay	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
2	<5	<25	Loam	Clay	<35%	750-950	Graded trenching
3	>5	<25	Loam	Clay	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
4	>5	<25	Loam	Clay	<35%	750-950	Graded trenching
5	<5	>25	Loam	Clay	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
6	<5	>25	Loam	Clay	<35%	750-950	Graded trenching
7	>5	>25	Loam	Clay	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
8	>5	>25	Loam	Clay	<35%	750-	Graded trenching

						950	
9	<5	<25	Clay	Clay	<35%	<=750	Graded trenching
10	<5	<25	Clay	Clay	<35%	750-950	Graded trenching
11	>5	<25	Clay	Clay	<35%	<=750	Graded trenching
12	>5	<25	Clay	Clay	<35%	750-950	Graded trenching
13	<5	>25	Clay	Clay	<35%	<=750	Graded trenching
14	<5	>25	Clay	Clay	<35%	750-950	Graded trenching
15	>5	>25	Clay	Clay	<35%	<=750	Graded trenching
16	>5	>25	Clay	Clay	<35%	750-950	Graded trenching
17	<5	<25	Loam	Clay	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
18	<5	<25	Loam	Clay	>35%	750-950	Graded trenching
19	>5	<25	Loam	Clay	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
20	>5	<25	Loam	Clay	>35%	750-950	Graded trenching
21	<5	>25	Loam	Clay	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
22	<5	>25	Loam	Clay	>35%	750-950	Graded trenching
23	>5	>25	Loam	Clay	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
24	>5	>25	Loam	Clay	>35%	750-950	Graded trenching
25	<5	<25	Clay	Clay	>35%	<=750	Graded trenching
26	<5	<25	Clay	Clay	>35%	750-950	Graded trenching
27	>5	<25	Clay	Clay	>35%	<=750	Graded trenching
28	>5	<25	Clay	Clay	>35%	750-	Graded trenching

						950	
29	<5	>25	Clay	Clay	>35%	<=750	Graded trenching
30	<5	>25	Clay	Clay	>35%	750-950	Graded trenching
31	>5	>25	Clay	Clay	>35%	<=750	Graded trenching
32	>5	>25	Clay	Clay	>35%	750-950	Graded trenching
33	<5	<25	Loam	Loam	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
34	<5	<25	Loam	Loam	<35%	750-950	Graded trenching
35	>5	<25	Loam	Loam	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
36	>5	<25	Loam	Loam	<35%	750-950	Graded trenching
37	<5	>25	Loam	Loam	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
38	<5	>25	Loam	Loam	<35%	750-950	Graded trenching
39	>5	>25	Loam	Loam	<35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
40	>5	>25	Loam	Loam	<35%	750-950	Graded trenching
41	<5	<25	Clay	Loam	<35%	<=750	Graded trenching
42	<5	<25	Clay	Loam	<35%	750-950	Graded trenching
43	>5	<25	Clay	Loam	<35%	<=750	Graded trenching
44	>5	<25	Clay	Loam	<35%	750-950	Graded trenching
45	<5	>25	Clay	Loam	<35%	<=750	Graded trenching
46	<5	>25	Clay	Loam	<35%	750-950	Graded trenching
47	>5	>25	Clay	Loam	<35%	<=750	Graded trenching
48	>5	>25	Clay	Loam	<35%	750-	Graded trenching

						950	
49	<5	<25	Loam	Loam	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
50	<5	<25	Loam	Loam	>35%	750-950	Graded trenching
51	>5	<25	Loam	Loam	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
52	>5	<25	Loam	Loam	>35%	750-950	Graded trenching
53	<5	>25	Loam	Loam	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
54	<5	>25	Loam	Loam	>35%	750-950	Graded trenching
55	>5	>25	Loam	Loam	>35%	<=750	Contour trenching (continuous contour trench/staggered contour trench)
56	>5	>25	Loam	Loam	>35%	750-950	Graded trenching
57	<5	<25	Clay	Loam	>35%	<=750	Graded trenching
58	<5	<25	Clay	Loam	>35%	750-950	Graded trenching
59	>5	<25	Clay	Loam	>35%	<=750	Graded trenching
60	>5	<25	Clay	Loam	>35%	750-950	Graded trenching
61	<5	>25	Clay	Loam	>35%	<=750	Graded trenching
62	<5	>25	Clay	Loam	>35%	750-950	Graded trenching
63	>5	>25	Clay	Loam	>35%	<=750	Graded trenching
64	>5	>25	Clay	Loam	>35%	750-950	Graded trenching

Table 2.9 Criteria for deciding horizontal and vertical intervals for Soil conservation treatments

Treatment	Slope %	Loamy		Clayey	
		VI	HI	VI	HI
Contour Bunding/TCB	<1	0.6	60	0.9	90
Contour Bunding/TCB	1 to 3	0.6	39	1	55
Contour Bunding/TCB	3 to 5	0.9	21	1.5	33
Contour Bunding/TCB	5 to 10	1.2	21	1.5	27
Graded Bunding	<=5	0.75-1.0		1 to 1.2	
Graded Bunding	5-10			0.75-1.5	
Trenching (Non arable land)	<5		10.0		10.0
Trenching (Non arable land)	5 to 10		7.5		7.5
Trenching (Non arable land)	10 to 25		5.0		5.0
Terracing	VI = Width x Slope/(100-Slope) for Black soil (batter slope 1:1; horizontal; vertical) VI =2 X Width x Slope/(200-Slope)-for Red and lateritic soils (batter slope 0.5:1) HI = Width / VI Note: For designing the Width = 200 x depth of cut / slope Depth of cut* = Profile depth x (1-(slope/100)) *minimum depth of cut = 0.3 m OR (Profile depth –(VI/2)) Note: Volume of earth excavation for Terrace strips are estimated using the formula: Q= LxWxD/8 Where, l = Length of the Terrace strip, W= Designed Terrace width, D= Fall between two Terrace strips				

**Note: ***This table needs refinement in future based on further research.

Source: Institution of Agricultural Technologists (IAT), 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru-560 052

Table 2.10 Criteria for deciding **Cross-section of structures-Contour Bund and TCB under field crops:**

Texture	Gravel	Depth	Top width	Base width	Height	Side slope	Cross section
Loam	>35%	<50	0.3	1.2	0.6	0.75:1	0.45
Loam	<35%	<50	0.3	1.5	0.6	1:1	0.54
Clay	<35%	<50	0.3	2.1	0.6	1.5:1	0.72
Clay	>35%	<50	0.3	2.1	0.6	1.5:1	0.72
Loam	<35%	50-75	0.3	1.5	0.6	1:1	0.54
Loam	>35%	50-75	0.3	1.5	0.6	1:1	0.54
Clay	<35%	50-75	0.45	2.0	0.75	1:1	0.92
Clay	>35%	50-75	0.45	2.0	0.75	1:1	0.92
Loam	<35%	75-100	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	75-100	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	75-100	0.45	2.4	0.75	1.3:1	1.07
Clay	>35%	75-100	0.45	2.4	0.75	1.3:1	1.07
Loam	<35%	100-150	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	100-150	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	100-150	0.6	3.1	0.7	1.78:1	1.29
Clay	>35%	100-150	0.6	3.1	0.7	1.78:1	1.29
Loam	<35%	>150	0.3	2.1	0.6	1.5:1	0.72
Loam	>35%	>150	0.3	2.1	0.6	1.5:1	0.72
Clay	<35%	>150	0.5	3.0	0.85	1.47:1	1.49
Clay	>35%	>150	0.5	3.0	0.85	1.47:1	1.49
Graded bunding							
clay	<35	50-100	0.3	1.2	0.5	0.9:1.0	0.375
clay	<35	50-100	0.3	1.2	0.6	0.75:1.0	0.45
clay	<35	50-100	0.3	2.1	0.6	1:1	0.72
clay	<35	100-150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
clay	>35	100-150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
clay	<35	>150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
clay	>35	>150	0.3	5.175	0.75	u/s 5:1 d/s 1.5:1	2.06
For Plantation crops							
Loam	>35%	<50	0.3	1.2	0.5	0.9;1	0.375

Source: Institution of Agricultural Technologists (IAT) 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru-560 052

Note: Length of side bund = 10% of main bund length

Source: Institution of Agricultural Technologists (IATA), 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru

Table 2.11 Criteria for selecting the **Cost rate** for conservation structures-**Contour bund/TCB**

Mode of execution	Gravel	Main/Side bund	Cost of bunding-per metre length of bund (Rs.) as per the cross section given below, [which is arrived as per the Table 2.9]							
a) **Black Soils/Red Soils**										
		Main bund section (Sq. meter)	0.375	0.45	0.54	0.72	0.92	1.07	1.29	1.49
		Side bund section (Sq. meter)	0.251	0.302	0.362	0.482	0.616	0.717	0.864	0.998
Machinery-WDD SOR	<35 % gravel	Main bund cost (Rs.)	25.11	28.61	33.40	42.49	57.79	68.26	81.49	91.21
		Side bund cost (Rs.)	18.47	21.29	24.08	31.17	41.94	46.61	53.98	60.61
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total		49.07	55.40	62.98	79.16	105.23	120.38	140.96	157.32
Machinery	>35 % gravel	Main	27.81	31.79	37.19	47.54	64.25	75.79	90.57	101.71
		Side	20.21	23.48	26.62	34.67	46.37	46.37	60.03	67.57
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total		53.52	60.77	69.31	87.71	116.12	127.66	156.09	174.77
b) Lateritic Soils										
Machinery		Main	33.55	38.80	44.86	58.15	77.56	95.73	110.48	126.58
		Side	23.69	27.65	31.63	41.35	54.91	54.91	71.99	81.38
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total		62.74	71.96	81.98	105.00	137.96	156.13	187.97	213.46
a) Black Soils/Red Soils										
MANUAL-**MGNREGS**	<35 % grav	Main	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
		Side	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22

	el	Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total		156.89	187.17	223.51	296.18	376.92	437.48	526.30	607.04
MANUAL- **MGNREGS**	>35 % gravel	Main	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
		Side	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	Total									
b) Lateritic Soils										
MANUAL		Main	90.66	108.79	130.54	174.06	222.41	258.67	311.85	360.20
		Side	60.74	72.89	87.46	116.62	149.01	173.31	208.94	241.34
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	TOTAL		156.89	187.17	223.51	296.18	376.92	437.48	526.30	607.04
a) Black Soils/Red Sandy Soils										
MANUAL- WDD SOR	<35 % gravel	Main	31.13	37.35	44.82	59.76	76.36	88.81	107.07	123.67
		Side	20.85	25.02	30.03	40.04	51.16	59.50	71.74	82.86
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	TOTAL		57.48	67.87	80.35	105.30	133.02	153.81	184.31	212.03
MANUAL	>35 % gravel	Main	34.13	40.95	49.14	65.52	83.72	97.37	117.39	135.59
		Side	22.86	27.44	32.92	43.90	56.09	65.24	78.65	90.85
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	TOTAL		62.49	73.89	87.56	114.92	145.31	168.11	201.54	231.94
b) Lateritic Soils										
MANUAL		Main	42.75	51.30	61.56	82.08	104.88	121.98	147.06	169.86
		Side	28.64	34.37	41.25	54.99	70.27	81.73	98.53	113.81
		WW	5.22	5.22	5.22	5.22	5.22	5.22	5.22	5.22
		Sowing of grass seeds	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
	TOTAL		76.89	91.17	108.31	142.57	180.65	209.21	251.09	289.17

SOR-2018-19, WW: Waste weir

Table 2.11(b) Criteria for selecting the cost rate for construction of Contour bund with Zingg Terrace - Summary of rates as per SOR 2018-19, (Rs/Ha) for use in DSS

Slope (%)	Cost (Rs/Ha)			
	Bund Section (Sq.m)			
	0.92	1.07	1.29	1.49
1-3	18801	25229	29995	33614
3-5	25069	32401	38464	43264

Note: Cost includes contour bunding/strengthening of existing bunds, waste weirs and sowing of seeds on the bunds.

Table 2.12 Criteria for selecting the cost rate for conservation of structures **- Graded bund.**

Soil Type	Gravel	Soil texture	Mode of execution	SOR	Cost of earth work per m.bund length.(Rs.) as per bund sections (m2) given below			
					0.375	**0.45**	**0.72**	**2.06**
a) Black Soils/Red Sandy Soils	<35%	Loam	Machinery	WDD	25.11	28.61	42.49	78.02
		Clay	Machinery	WDD	25.11	28.61	42.49	78.02
	>35%	Loam	Machinery	WDD	27.81	31.79	47.54	0.00
		Clay	Machinery	WDD	27.81	31.79	47.54	0.00
b) Lateritic Soils	<35%	Lateritic	Machinery	WDD	33.55	38.80	58.15	187.46
	>35%	Lateritic	Machinery	WDD	33.55	38.80	58.15	187.46
a) Black Soils/Red Sandy Soils	<35%	Loam	Manual	MGNREGS	90.66	108.79	174.06	498.00
		Clay	Manual	MGNREGS	90.66	108.79	174.06	498.00
	>35%	Loam	Manual	MGNREGS	90.66	108.79	174.06	498.00
		Clay	Manual	MGNREGS	90.66	108.79	174.06	498.00
b) Lateritic Soils	<35%	Lateritic	Manual	MGNREGS	90.66	108.79	174.06	498.00
	>35%	Lateritic	Manual	MGNREGS	90.66	108.79	174.06	498.00
a) Black Soils/Red Sandy Soils	<35%	Loam	Manual	WDD	31.13	37.35	59.76	170.98
		Clay	Manual	WDD	31.13	37.35	59.76	170.98
	>35%	Loam	Manual	WDD	34.13	40.95	65.52	187.46
		Clay	Manual	WDD	34.13	40.95	65.52	187.46
b) Lateritic Soils	<35%	Loam	Manual	WDD	42.75	51.30	82.08	234.84
	>35%	Clay	Manual	WDD	42.75	51.30	82.08	234.84

SOR-2018-19

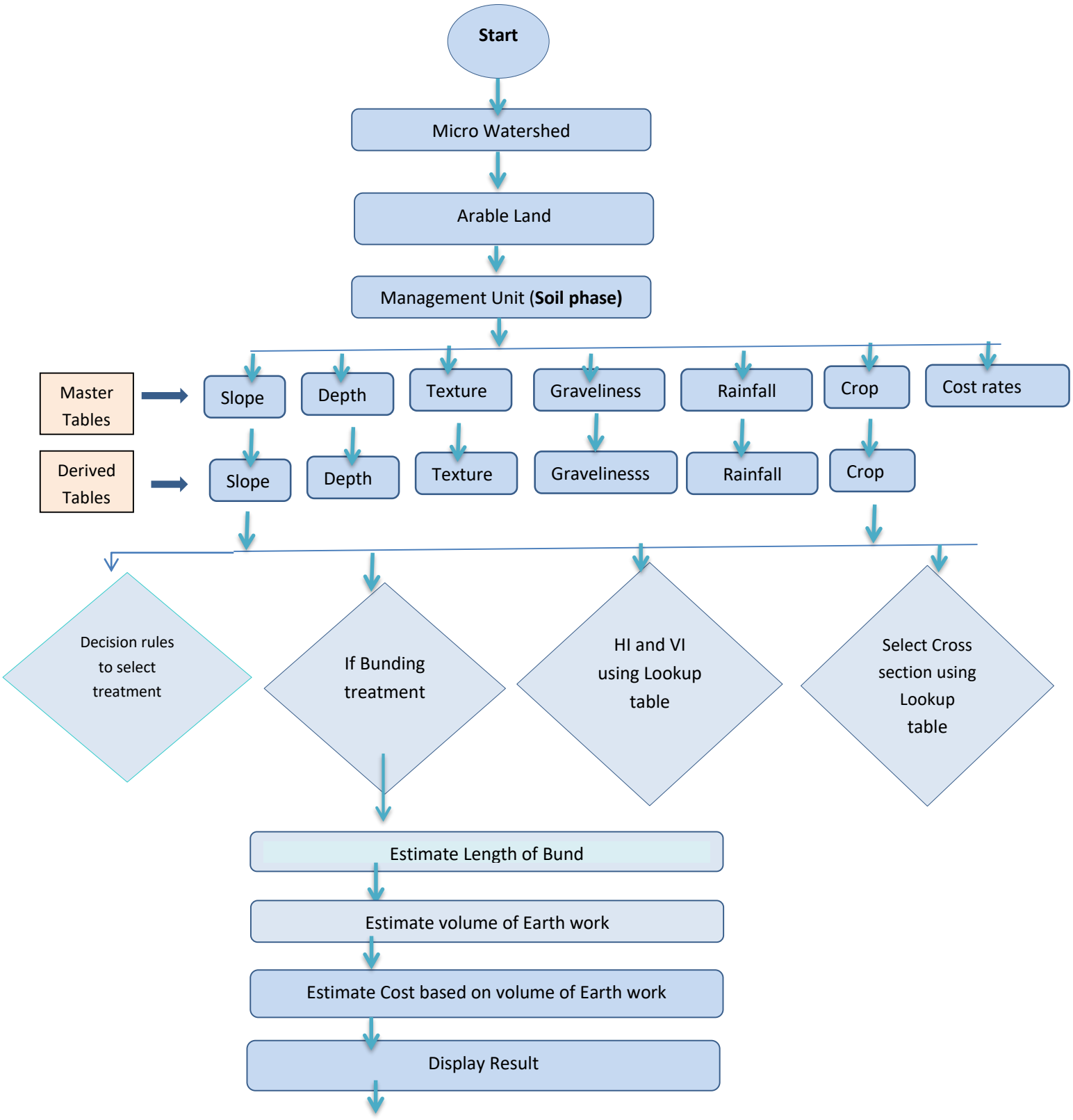
Table 2.13 Criteria for selecting the cost rate for conservation structures-channel weir in **graded bunds**

Costing for channel weir in graded bund		
Bund section Sq.m	Average cost/ channel weir.	Average cost/ channel weir.
0.375	992	1117
0.45	1016	1142
0.72	2092	2164
2.06	10054	1087
	Note:WDD SOR 2018-19	Note: MGNREGA SOR 2018

Note: Average of one channel weir for every 100 meters' bund length. Depending on the slope, it will vary from 3 to 5 per ha area.

Table 2.14 Step-by-step execution of conservation plan-**Arable land Treatment (Fig.2.1a)**.

Steps	Description
1	Read Management Unit (Soil phase) wise soil and land characteristics data.
2	Select treatment for land characteristics based on decision rules
3	Select vertical and horizontal interval based on decision rules (Table 2.9)
4	Select cross-section of structure based on the decision rules (Table 2.10)
5	Estimate length of Bunding per hectare (m)= 10000 x S/(VI*100)
6.	Estimate cost of conservation structure based on decision rules (Table-2.11for Contour Bunding and TCB, Table 2.12.and 2.13 for Graded bunds.
7.	Display results: Parcel No. Name of the farmer Area (Ha. and in Acres) Treatment Length(m.)/No. Cost Conservation practices



Micro Watershed	Survey Number	Farmer name	Area in Hectare /Acres	Treatment type	Length (Meters)	Main Bund Cost (in Rs)	Side Bund Cost (in RS)	Cost of Waste weir (COF)	Total cost	Conservation practice

Fig. 2.1a Schematic figure for deciding the structures and cost for **Arable Land**

Steps involved in the execution of DSS on Soil and water conservation structures (Fig.2.1b).

- User will select the District, Taluk, Village, and/or Watershed Name and Survey number. User will also be able to enter the XY coordinates as Lat-Long.
- A query will be executed to find the details about the selected survey number.
- If user enters XY coordinates, get the information of the selected parcel
- Finding Slope, Depth, Texture, Gravel, LCC, Landform, for the selected survey number from Land Parcel characteristic table.
- Fetching average Rainfall for the year.
- Based on LCC and Landform, get soil type which is "Arable soil Red/Lateritic or Arable soil black or "Non arable soil"
- Search for derived slope against actual slope based on soil type
- Search for derive soil depth against actual soil depth based on soil type
- Derived Texture against actual Texture.
- Get derived Gravel against actual Gravel.
- Get derived Rainfall against actual rainfall based on Soil type.
- Find Treatment from the soil type and slope, depth, texture, Gravel, and rainfall.
- Finding horizontal and vertical interval on the basic of treatment and slope and texture and Depth.
- Finding value of main cross section based on texture, gravel, slope, depth, VI and HI. Side cross section = 2/3 X Main cross section.
- Find the length of the structure
    - Length per hectare (m) = 10000 X S/(VI*100)
- Find the Cost for the Construction of using Treatment, soil, gravel, cross section.

Display the result in a table showing the information such as Watershed name, survey number, Area in Hectare as well as information related to Treatment proposed, its length, cost for the main bund, cost for side bund, Total cost and also cost of Waste Weir.

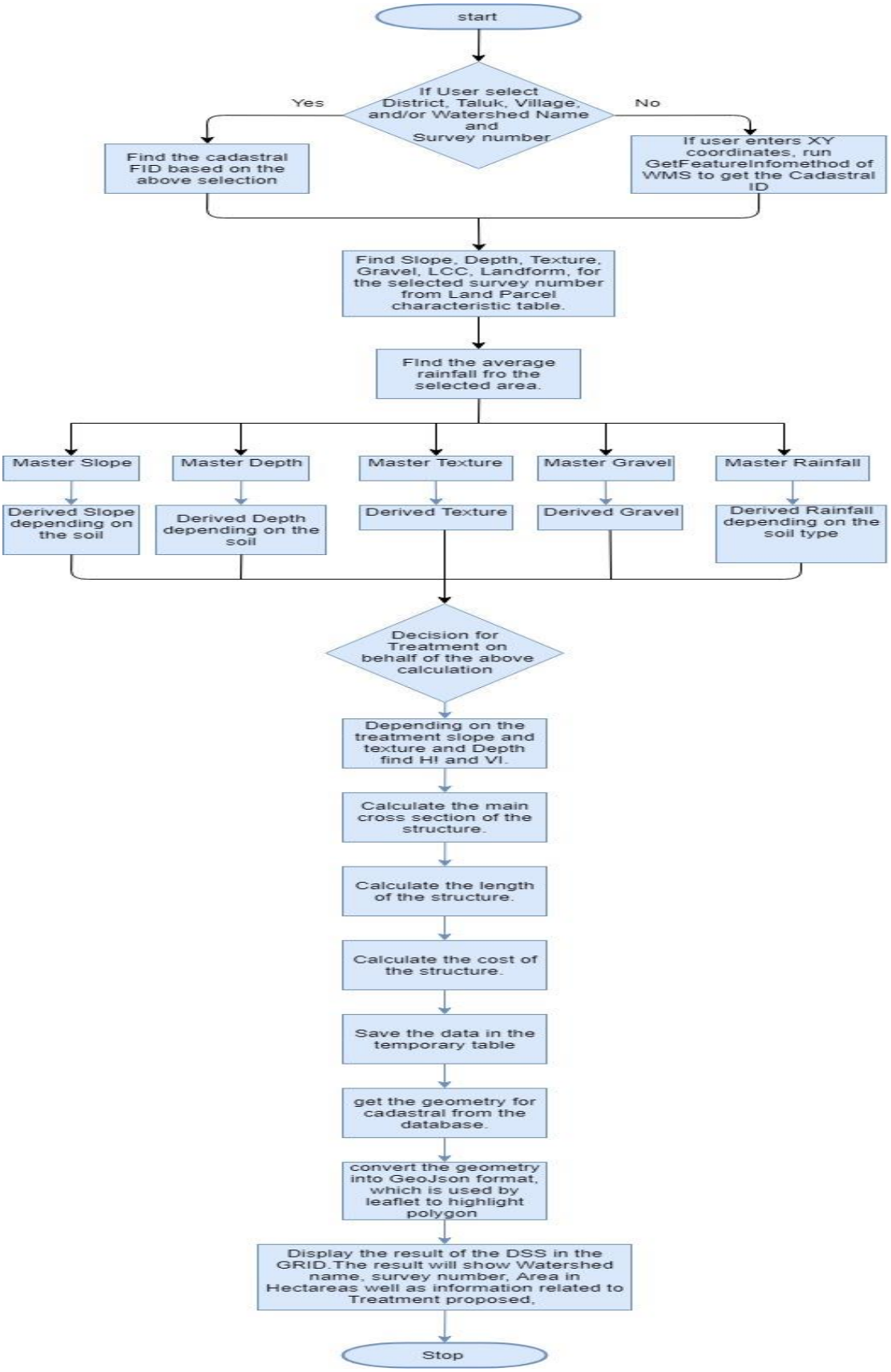


Fig.2.1b Flow diagram for the execution of DSS on conservation Plan for **Arable Land**

Criteria for selection of costing for **Bench Terraces:**

Table-2.15 Sloping inward terrace -riser 0.5:1.0; H:V in red and lateritic soils (mostly loamy soils)

S.No.	Land Slope (%)	Profile Depth (cm)	Total Cost of Terracing (Rs. /Ha)
1	10 to 15	25-50	107450
2	15 to 25	25-50	121591
3	>25	25-50	136389
7	10 to 15	>50	281957
8	15 to 25	>50	276907
9	>25	>50	271622

Note: 1. Costing is as per WDD SOR-2028-19
2. Cost of terracing includes 0.06m^2 Lip Bund, 0.3m thick stone pitching of the Riser, waterways with drops, survey and alignment charges

Table-2.16 Sloping inward terrace-riser 1:1; H: V in Black soils (clayey soils) Rainfall >750 mm

S.No.	Land Slope (%)	Profile Depth (cm)	Total Cost of Terracing (Rs. /Ha)
1	10 to 15	25-50	101470
2	15 to 25	25-50	111228
3	>25	25-50	120846
7	10 to 15	>50	266329
8	15 to 25	>50	253435
9	>25	>50	240726

Note: 1. Costing is as per WDD SOR-2028-19
2. Cost of terracing includes 0.06m^2 Lip Bund, 0.3m thick stone pitching of the Riser, waterways with drops, survey and alignment charges

Table-2.17. Sloping Outward terrace-riser 1:1; H: V in loamy (red) /clayey soils

S.No.	Land Slope (%)	Profile Depth (cm)	Total Cost of Terracing (Rs. /Ha)
1	10 to 15	25-50	505561
2	15 to 25	25-50	704397
3	>25	25-50	900386
7	10 to 15	>50	516473
8	15 to 25	>50	548703
9	>25	>50	580470

Note: 1. Costing is as per WDD SOR-2028-19

2. Cost of terracing includes 0.54m^2 Lip Bund, 0.3m thick stone pitching of the Riser, waterways with drops, survey and alignment charges

Table-2.18. Plantation terraces with 1:1; H: V RISER

S.No.	Land Slope (%)	Profile Depth (cm)	Total Cost of Terracing (Rs./Ha)
1	10 to 15	25-50	117106
2	15 to 25	25-50	192055
3	>25	25-50	276371
7	10 to 15	>50	71481
8	15 to 25	>50	117228
9	>25	>50	168

Note: 1. Costing is as per WDD SOR-2028-19

2. Cost of terracing includes 0.54m^2 Lip Bund, 0.3m thick stone pitching of the Riser waterways with drops, survey and alignment charges.

Table 2.19 Steps involved in conservation planning for **Non-Arable lands (**Fig. 2.2)

Steps	Description
1	Read Management unit (Soil phase) wise soil and land characteristics data.
2	Select treatment for land characteristics based on decision rules
3	Select or vertical and horizontal interval based on decision rules (Table 2.9)
4	Select cross-section of structure based on the decision rules Table 2.)
5	Decide volume of earth work using cross section of structure -horizontal interval Contour Trench/ Staggered Trench based on decision rules (Table-2.24)
6.	Estimate cost of conservation structure based on decision rules (Table 2.25) for Trenching.
7.	Display results: Parcel No. Area (Ha.) Treatment Length(m.)/No. Cost

Table 2. 20 Criteria for selecting the dimensions for opening of Trenches

Dimension of trenches:

Contour trench		Staggered trench					
Width (m.)	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Depth (m.)	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Length (m.)1*	15.0	4.0	6.0	8.0	10.0	12.0	15.0
Quantity per Trench (Cum)	4.05	1.08	1.62	2.16	2.7	3.24	4.05

NOTE: 1* Decided based on the presence of obstacles (rock out crop/trees) on the ground surface.

Table 2. 21 Criteria for selecting the quantity of earth excavation for opening of Trenches

TRENCHING				
Sl. No.	Slope	Horizontal interval	Volume of earth Excavation (m^3) per ha.	
	%	(m)	Continuous Contour trenches	Staggered Contour trenches
1.	5	10.0	218.7	169.8
2.	5 to 10	7.5	291.6	222.2
3.	10 to 15	5.0	434	321.4

Source: Horizontal interval: Institution of Agricultural Technologists (IAT), 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru-560 052.

Table 2.22Criteria for deciding cost of S**taggered Contour Trenches**

STAGGERED CONTOUR TRENCH									
	TRENCH DIMENSIONS								
	Wdth		m.	0.60	0.60	0.60	0.60	0.60	0.60
	Depth		m.	0.45	0.45	0.45	0.45	0.45	0.45
	length		m.	4.00	6.00	8.00	10.00	12.00	15.00
	Earth work Quantity per Trench		m^3.	1.08	1.62	2.16	2.7	3.24	4.05
SLOPE	HORIZONTAL INTERVAL	EARTH WORK							
%	(m)	QUANTITY PER Ha. (m^3)	SSR CODE NO.	LAND	RATE (Rs.)	AMOUNT (Rs.)			
5	10.0	169.8	2.3(A)	Arable	83	12328.30			
		169.8	2.3(B)i	Non-Arable : Ordinary Soil	83	12328.30			
		169.8	2.3(B)ii	Non-Arable : Hard Soil	91	13330.19			
5 to 10	7.5	222.2	2.3(A)	Arable	83	16133.33			
		222.2	2.3(B)i	Non-Arable : Ordinary Soil	83	16133.33			
		222.2	2.3(B)ii	Non-Arable : Hard Soil	91	17444.44			
10 to 20	5.0	321.4	2.3(A)	Arable	83	23335.71			
	5.0	321.4	2.3(B)i	Non-Arable : Ordinary Soil	83	23335.71			
	5.0	321.4	2.3(B)ii	Non-Arable : Hard Soil	91	25232.14			

Table 2.23 Criteria for selecting the cost rate for construction of structures - **Trenching.**

Soil type	Gravel	Soil	Mode of execution	SOR	Cost of earth work per m. length 0f trench (Rs.) trench section: 0.27m^2
a) Black Soils/Red Sandy Soils	<35%	loam	manual	WDD	22.41
		clay	manual	WDD	22.41
		lateritic	manual	WDD	24.57
b) Hard Soils	>35%	loam	manual	WDD	22.41
		clay	manual	WDD	22.41
		lateritic	manual	WDD	24.57

SOR-2018-19

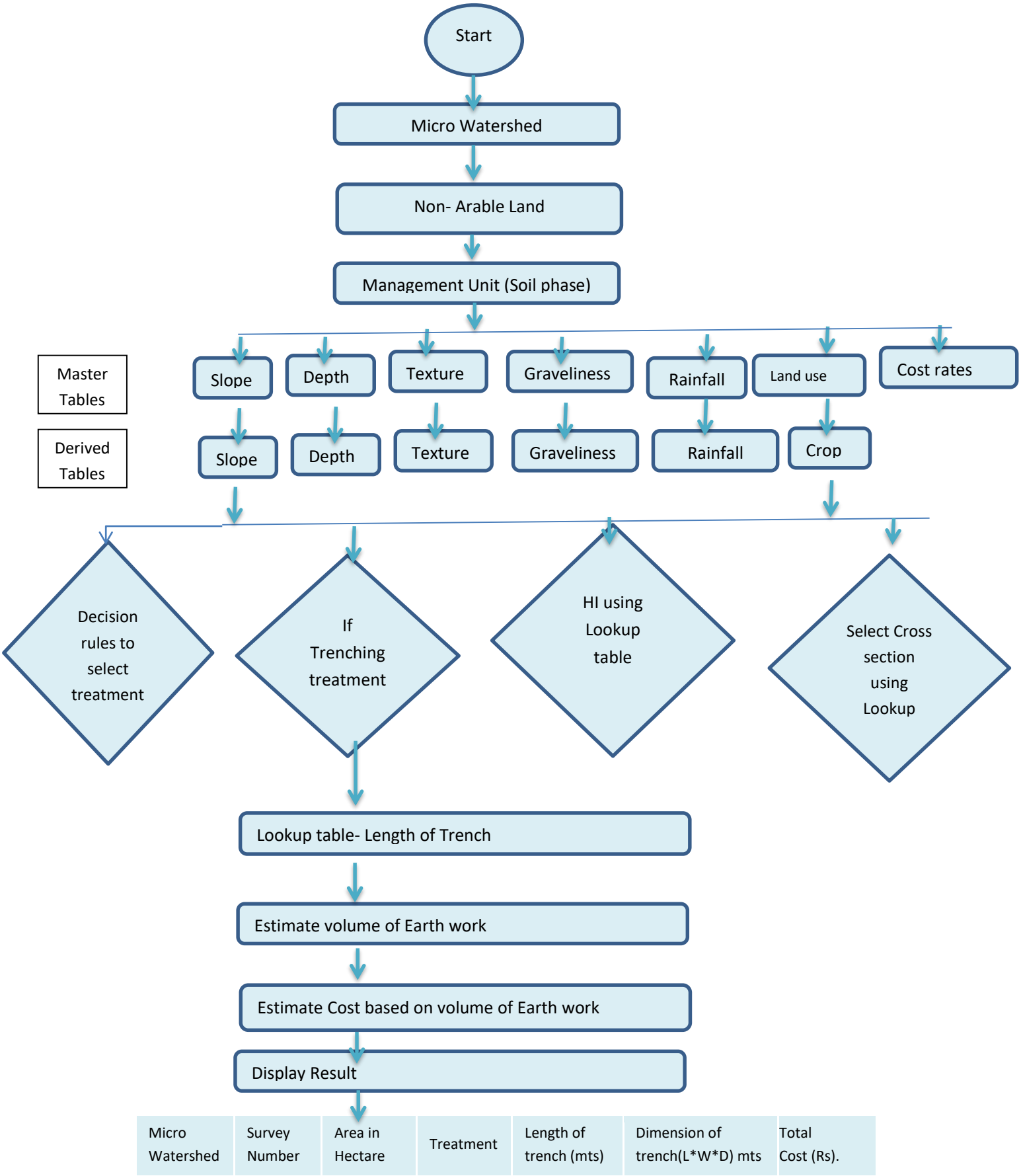


Figure 2.2 Flow diagram for deciding **dimensions** & **cost of Trenches** in **Non-arable Lands**

DSS for Crop Selection (Based on Physical suitability and B: C Ratio)

The land suitability assessment provides the suitability or otherwise of the various land resources occurring in an area for major crops grown. This helps to find out specifically the suitability of the land resources like soil, water, weather, climate and other resources and the type of constraints that affect the yield and productivity of the selected crop.

This assessment is based on the model proposed by Food and Agricultural Organisation (FAO, 1976 and 1983) to assess the resources of an area for specific land use/crop. In this assessment, the specific requirements of a crop (compiled from the existing literature) are compared with the characteristics of land and suitability of the area for the crop is arrived at based on the matching. If the land characteristics of an area match the requirements of the selected crop then the area is considered as suitable for the crop, otherwise it is grouped as not suitable for the crop. The site-specific land resources database generated through LRI helps to establish the suitability of the resources to any selected crop for the area in a very objective manner, which was not possible earlier with general datasets.

Source:

1. FAO (1976), Framework for Land Evaluation, Food and Agriculture Organization, Rome.72 pp
2. FAO (1983), Guidelines for Land Evaluation for Rainfed Agriculture, FAO, Rome. 237 pp.
3. Naidu, L.G.K., Ramamurthy, U. Rajendra Hegde, Challa, O., Krishnan, P., and Gajbhiye, K.S., 2003, Soil suitability criteria for major crops, NBSSLUP, Tech Report No:582, Nagpur
4. Mandal, C., Mandal, D.K, Srinivas, C.V, Sehgal, J and Velayutham, M., 1999; Soil climatic database for crop planning in India, NBSSLUP publication 53, 1014, NBSSLUP, Nagpur, India. Page no. 142

Structure of the classification

In land suitability classification there are four categories, namely orders, classes, subclasses and units. At the order level, the mapping units are grouped into suitable or not suitable based on kinds of suitability for the selected land use. The orders are divided into classes based on degrees of suitability and the classes are further divided into subclasses based on the kinds of limitations. Land suitability subclasses are divided into land suitability units based on specific management requirements. The ratings used for defining each class are based on the number and degree of limitations present.

A brief description of the orders, classes and subclasses used in the suitability assessment of major crops is given below:

Order S (Suitable)

Class S1	*(Highly suitable) Land unit having no limitation for sustainable use or with not more than three slight limitations.*
Class S2	(Moderately suitable) Land with more than three slight limitations but with not more than three moderate limitations.
Class S3	(Marginally suitable) Land with more than three moderate limitations but with not more than two severe limitations.

Order N (Not Suitable)

Class N1	:	(Currently not suitable) Land with severe or very severe limitations that may be overcome in time but cannot be corrected with existing knowledge at current acceptable cost.
Class N2	:	(Permanently not suitable) Land having limitations that will be very difficult to correct and use

There are no sub-classes within the suitability class S1. Classes S2, S3 and N1 are divided into subclasses based on the specific limitations encountered in an area for the selected land use. The specific limitations that are likely to affect crop production at the watershed or village level are indicated below with their symbols to be used.

Erratic rainfall and its distribution and short growing period	*c*
Erosion hazard (Slope and erosion)	*e*
Soil depth (rooting conditions)	*d*
Soil texture (lighter or heavy texture)	*t*
Coarse fragments (gravelliness or stoniness)	*g*
Soil fertility constraints, calcareousness, sodicity hazard, salinity problem etc.	*n*
Drainage problem	*w*
Moisture availability	*m*
calcareousness	*z*
Topogrphy	*l*

Note: Additional limitations and changes, not provided in FAO, are from NBSS

Limitations are indicated in lower case letters after the suitability class symbol. For example, marginally suitable land with low rainfall or short growing period as a limitation is designated as S3c. Normally two and sometimes three limitations are included at subclass level. Land suitability units are indicated by the Arabic numbers after the limitation symbol. In assigning the overall suitability class to any area, **the limitation approach or law of the minimum** is followed. According to this approach, even if all other factors are favourable for the crop and only one factor is likely to be a limitation, then that factor is given precedence in assigning the suitability class.

Land suitability assessment for major crops grown in the watershed areas

Based on the suitability classification, land resources of any watershed or area can be evaluated to find out their suitability for various crops, like cereals and millets, oil seeds, pulses, commercial crops like cotton, sugarcane, spices and horticultural crops. The assessment can be done for the existing crops that are under cultivation at present or for some of the promising crops and varieties from other places before they are recommended for cultivation in the area.

The process involved in the crop suitability assessment is elaborated below.

- Selection of the crop and the survey number or farmer's field to be assessed for suitability evaluation
- Finalisation of suitability criteria for the crop or crops to be assessed. The criteria table developed for each crop will show the soil-site and other land characteristics on one side and the range of values assigned to each of the land characteristics for different suitability classes like Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Not Suitable (N2) on the other side.
- Run the system to match the crop suitability criteria with LRI, Hydrology and other resource information pertaining to the farm/survey number stored in the system.
- After the matching process, the system displays the degree of suitability for the crop with constraints if any as subscripts after considering the following criteria/logic
  - Law of Minimum / Limitation approach in assigning the degree of suitability.
  - Internal prioritization among crops with same rank.
  - Displaying the suitable crops (on prioritization basis), with all limiting factors as sub-script.
- Based on the soil, site, climate and other datasets, the system calculates the number of S1s, S2s and S3s against the parameters provided with each crop matrix. Then the crop is placed into a suitability class/category based on the law of minimum as illustrated below.

  Example:

  Sorghum: 4S1 + 3S2 + 4S3 ~ will be placed in to S3 (Internal prioritization based on the Law of Minimum approach)

  Maize: 1S1 + 10S2 + 0S3 ~ will be placed in to S2 (Internal prioritization based on the Law of Minimum approach)

  Red gram: 15S1 + 0S2 + 0S3 ~ will be placed in to S1 (Since there is no limitation for the crop)

  Maize S2, Groundnut S2-Selection of the most suitable crop among the two will be based on B:C Ratio as the score for both crops are same.

Table 3.1 Steps involved in the execution of crop suitability DSS

Step	Methodology	Remarks
1	Compare all biophysical layers and compare it with given crop suitability	(S1 is highly suitable, S2 is moderately suitable and S3 is

	criteria and assign Classes of Suitability based on Law of Minimum and count all score values for first crop.	marginally suitable; N1 is Currently Not Suitable and N2 is Permanently Not Suitable)
2	Iterate the Step 1 for all the crops in database and assign the scores.	
3	Internal prioritization needs to be done for the crops assigned with same rank.	a. Exclude the crop which gets the rank "N" b. Among the crops with same rank, the crop which gets more S1 will be prioritized. b. In case same number of S1/S2/S3 are observed, then B:C ratio will be taken into consideration.
4	Displaying the suitable crops (on prioritization basis) along with B:C Ratio, indicating all limiting factors as sub-script.	

As there is no dynamic data entering in to the system, the system can calculate crop suitability for all the land parcels (Survey Numbers) before Go Live and the same can be stored in static database tables which can be retrieved swiftly whenever request arises from end user/ Manager / Policy Maker. However, in course of time parameter data may get changed and to capture this Batch jobs can be run during less intensive hours periodically to update the tables. Appropriate indexes also need to be built on these tables for quick retrieval of the information.

Benefit Cost Ratio:

Benefit cost ratio is decided based on standard cost of cultivation, yield and dynamic market prices. The standard cost of cultivation for any crop is available with the Department of Agriculture. Market prices can be obtained from Agmarketnet web API. Using the above the B:C Ratio can be calculated as (Yield X Market Price) / Cost of Cultivation. In Karnataka, the B:C Ratio values are calculated for major crops every year by the Karnataka State Agricultural Market Prices Committee (KSAPC) and the same can be taken as standard and used for deciding the suitability classes (Table 3.2).

The Crop suitability choices arrived for an area need to be displayed/shared to the concerned agricultural office/stakeholders and vetted before the same is recommended to the farmer. This assessment can help greatly in identifying the best suited areas and the areas having limitations in the watershed area. Similar assessments can be made for other areas and for other crops for the same area.

The most important thing to be noted in carrying the suitability assessment is the development of Land suitability criteria for various crops (Cereals, pulses, oilseeds,

horticultural crops, fodder crops, forestry sp.etc.). Right now, the land suitability criteria compiled and published by NBSS (Naidu et al 2002) will be used for assessing the suitability of the land resources for various crops in the state. The criteria may need refinement, which can be done after receiving the comments from the project partners, department of agriculture and horticulture, line departments, KVKs, research stations and other stakeholders.

Table 3.2a **Cost Benefit Ratio** (B: C Ratio) of **Agriculture and Horticulture crops** (2016-17) as per Karnataka Agriculture Price Commission, Dec. 2017, DOA, Bengaluru-560001

S.No	Crop Name	Cost of cultivation Rs/Acre	Gross income Rs/Acre	Net income Rs/Acre	Cost Benefit ratio
1	Paddy irrigated	56160	56160	-484	0.99
2	Paddy rainfed	39438	23768	-15670	0.6
3	Ragi	32412	24876	-7536	0.76
4	Hybrid Jowar	22638	12992	-9646	0.57
5	Rabi Jower	22185	15849	-6336	0.71
6	Hybrid Maize	32482	30559	-1923	0.94
7	Bajra	20621	9972	-10649	0.49
8	Tur (Red gram)	39896	30481	-9415	0.76
9	Green gram	23751	19158	-4232	0.82
10	Black gram	24619	18562	-6057	0.75
11	Bengal gram	27224	20645	-6579	0.76
12	Groundnut	30371	21809	-8992	0.72
13	Soybean	27399	18911	-8488	0.69
14	Sunflower	25166	17933	-7173	0.72
15	Cotton	52724	51373	-1351	0.97
16	Dry chillies	75969	67678	-8291	0.89
17	Tomato	178759	182623	3863	1.02
18	Onion	53340	46820	-6520	0.88
19	Potato	88159	82642	-5517	0.94
20	Banana Yelakki	165880	210654	44774	1.27
21	Banana-Pachabale	197675	347878	150203	1.76
22	Grapes- Table	288655	218151	-70504	0.76
23	Grapes-Resin	333463	291918	-44545	0.88
24	Grapes-Blue	260357	276391	16033	1.06
25	Pomegranate	219256	279688	60432	1.28
26	Mango	56153	65036	8883	1.16
27	Coconut	68383	31365	-37018	0.46
28	Copra coconut	79335	59260	-20076	0.75
29	Aracanut-red boiled	194116	223500	29384	1.15
30	Aracanut-white	187364	229637	42273	1.22
31	Ginger	228474	288436	59961	1.26

32	Turmeric	185836	283818	97983	1.53
33	Black pepper	129008	165599	36591	1.28

Table 3.2b Cost Benefit Ratio (B: C Ratio) of **Vegetables**

Vegetable Crops	Cost of cultivation Rs/Acre	Gross income Rs/Acre	Net income Rs/Acre	Cost Benefit Ratio
Beans (cluster, pole, dolichos, French, broad)	104218	87480	-16738	0.84
Beetroot	70551	71600	1049	1.01
Bitter gourd	95519	70200	-25319	0.73
Brinjal	63442	71000	7558	1.12
Cabbage	105645	95647	-9998	0.91
Capsicum	228203	208000	-20203	0.91
Carrot	77007	74860	-2148	0.97
Cauliflower	95959	97096	1138	1.01
Chow-chow	174989	169290	-5699	0.97
Cucumber	78892	79900	1008	1.01
Gherkin	120908	126250	5342	1.04
Gourd (bottle, ash, snake)	128320	132250	3930	1.03
Green chillies	102604	130220	27616	1.27
Greens (amaranthus, palak, coriander)	68568	63934	-4635	0.93
Knol-khol	63909	60992	-2917	0.95
Muskmelon	96723	82800	-13923	0.86
Okra	79113	78750	-363	1
Onion (Irrigated)	99196	120525	21329	1.22
Onion (rain fed)	41031	39360	-1671	0.96
Peas	65513	63460	-2053	0.97
Potato (irrigated)	103999	92293	-11707	0.89
Potato (rain fed)	56379	53036	-3343	0.94
Potato (Drip irrigated)	116209	101748	-14461	0.88
Potato (Furrow)	111537	96633	-14904	0.87
Potato(sprinkler)	88200	89050	7177	1.01
Pumpkin	61918	64110	2182	1.04
Ridge gourd	93828	72288	-21540	0.77
Rose onion	73725	84828	11103	1.15
Tomato (Rain fed)	66867	90400	23533	1.35
Tomato(Drip irrigated)	149820	152150	2330	1.02
Tomato(furrow Irrigated)	124099	125600	1501	1.01
Water melon	103036	109880	6844	1.07
Curry leaf	74624	108000	33376	1.45
Drumstick	70837	60858	-9979	0.86
Ridge gourd	93828	72288	-20540	0.77
Source: UAS Bangalore, Department Agriculture Economics				

Table 3.2c Cost Benefit Ratio (B: C Ratio) of **Flowers**

Flower Crop	Cost of cultivation Rs/Acre	Gross income Rs/Acre	Net income Rs/Acre	B: C Ratio
Jasmine (Kakada)	147687	256259	108572	1.74
Jasmine (Udupi)	204256	359718	155462	1.76
Rose(open) cut flowers	194812	262080	67268	1.35
Rose (open) bunches	223242	329280	106038	1.47
Bird of Paradise	226154	330480	104326	1.46
Crosandra	166686	217000	50314	1.3
Aster	94705	98271	3566	1.04
Marigold	96594	78000	-18594	0.81
Chrysanthemum	264226	224531	-39695	0.85
Tuberose	163088	154000	-9088	0.94
Source: UAS Bangalore, Department Agriculture Economics				

Table 3.2d Cost Benefit Ratio (B: C Ratio) of Spices and **Plantation crops**

Spices & Plantation crops	Cost of cultivation Rs/Acre	Gross income Rs/Acre	Net income Rs/Acre	B: C Ratio
Coconut tall	46525	36624	-9901	0.79
Coconut dwarf	77253	72409	-4845	0.94
Cashew	70630	70286	-344	1
Cocoa	111970	104400	-7570	0.93
Oil palm	48108	55290	7182	1.14
Tamarind	36226	36573	347	1.01
Beetle vine	223874	240400	16526	1.07
Pepper	227177	269184	42007	1.29
Cardamom	115927	112470	-3457	0.97
Garlic	123495	173800	50535	1.41
Ginger	216193	377576	161383	1.75
Turmeric	132976	169440	36464	1.27
Redchillies (irrigated)	99630	128800	29170	1.29
Redchillies (rainfed)	35475	36840	1365	1.04
Coriander seed	36540	31875	-2741	0.87
Source: UAS Bangalore, Department Agriculture Economics				

Module Description for the execution of DSS on Crop Suitability

After successful login, user will click on 'Crop Selection' under Decision Support System. A web page for Crop selection will be displayed to user.

- The web page will have the drop down for selecting District, Taluk, Village, Watershed name, Survey Number, Season as well as will have the drop down for selecting Crop and Suitability.
- User will be able to select the District, Taluk, Village, Survey Number, Watershed and Season.
- A query will be executed to find the details about the survey number.
- System will fetch the information such as Nutrient parameters, soil characteristics against the respective survey Number.
- Get the Rainfall data based on the nearest rain gauge station.
- If user has not selected the crop, get the Crop list from the Master-Crop depending upon the season selected.
- Follow below steps for each crop from the Crop list or crop which user has selected.
    - Get the distinct sub-categories (Parameters) from Land Suitability Crop for the selected crop
    - Derive the suitability (i.e. S1/S2/S3/N) for each parameter by comparing it with the actual values for the respective cadastral ID.
    - Save the information of the crop, with suitability (S1, S2, S3, and N) based on CADASTRAL_ID on DSS2_Parameter_sutability database.
- Count the number of S1, S2, and S3 against each crop and rank the crop which gets more S1. If the number of S1, S2, S3 values are the same then fetch the B: C ratio from Master B:C Ratio against respective crop. Whichever crop is having highest BC ratio will be prioritized.
- Fetch the Farmer Name from Land_Parcel_Information table against the selected S. Number. This table will be populated using the web service from BHOOMI.
- Result displays the type of Crop for the Survey Number, with Season, Suitability Class, Benefit Ratio and the Rank. System will also highlight the Land parcel related to the selected survey number in GIS map.
- System will provide the result displaying suitability of the selected crop as well as system will display the message ". For More information please contact << Number >> << Name of the Person>>". Fetch the number and name from Master Experts table. Also, Link will be provided to open the Package of Practices. On click of link PDF of Package of Practices will be displayed.
- Display the Farm owner details based on the data fetched for the cadastral number through web service integration with Bhoomi.
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyse DSS results based on these temporary changes.

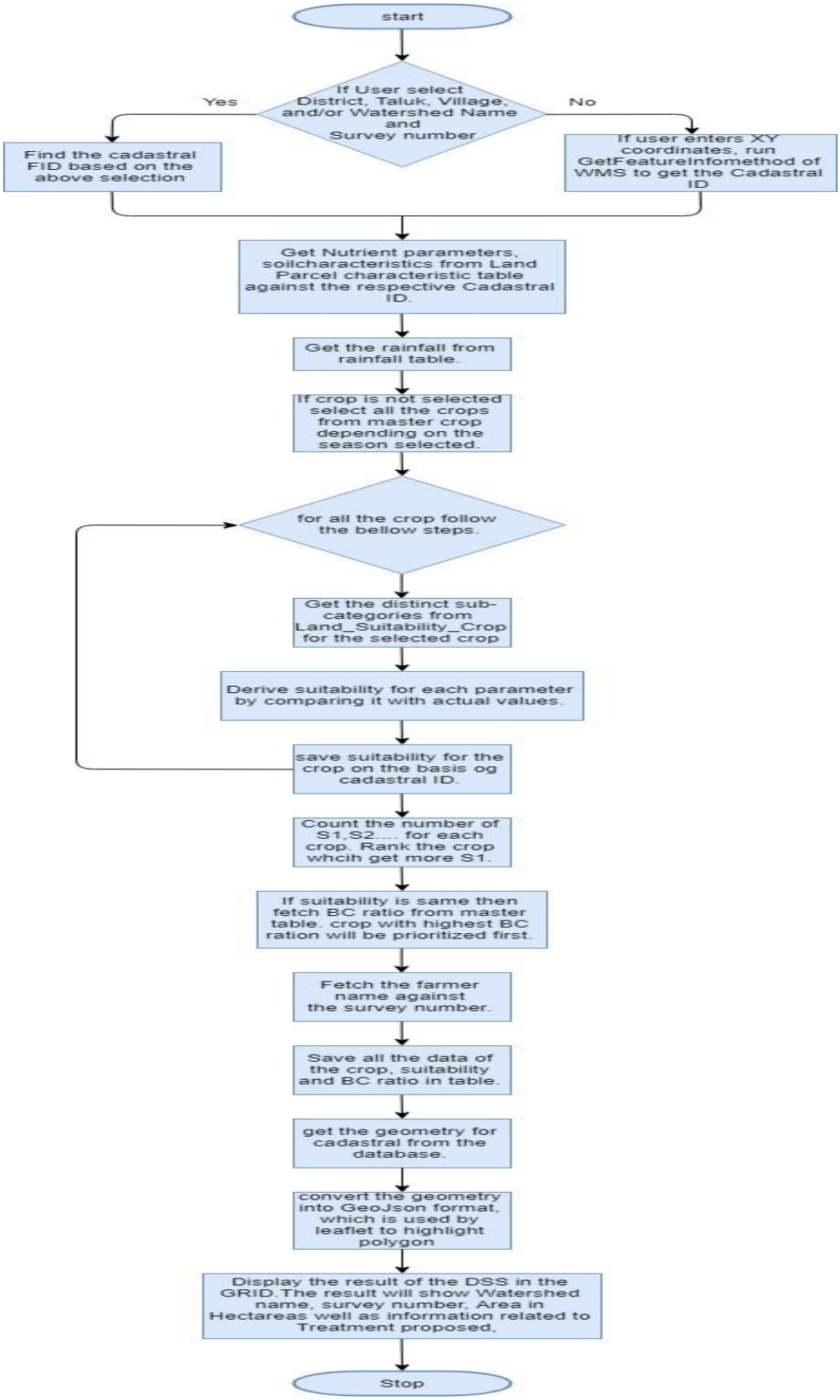


Figure 3.1 Revised Flow chart as per LLDD for the execution of the DSS on Crop Suitability

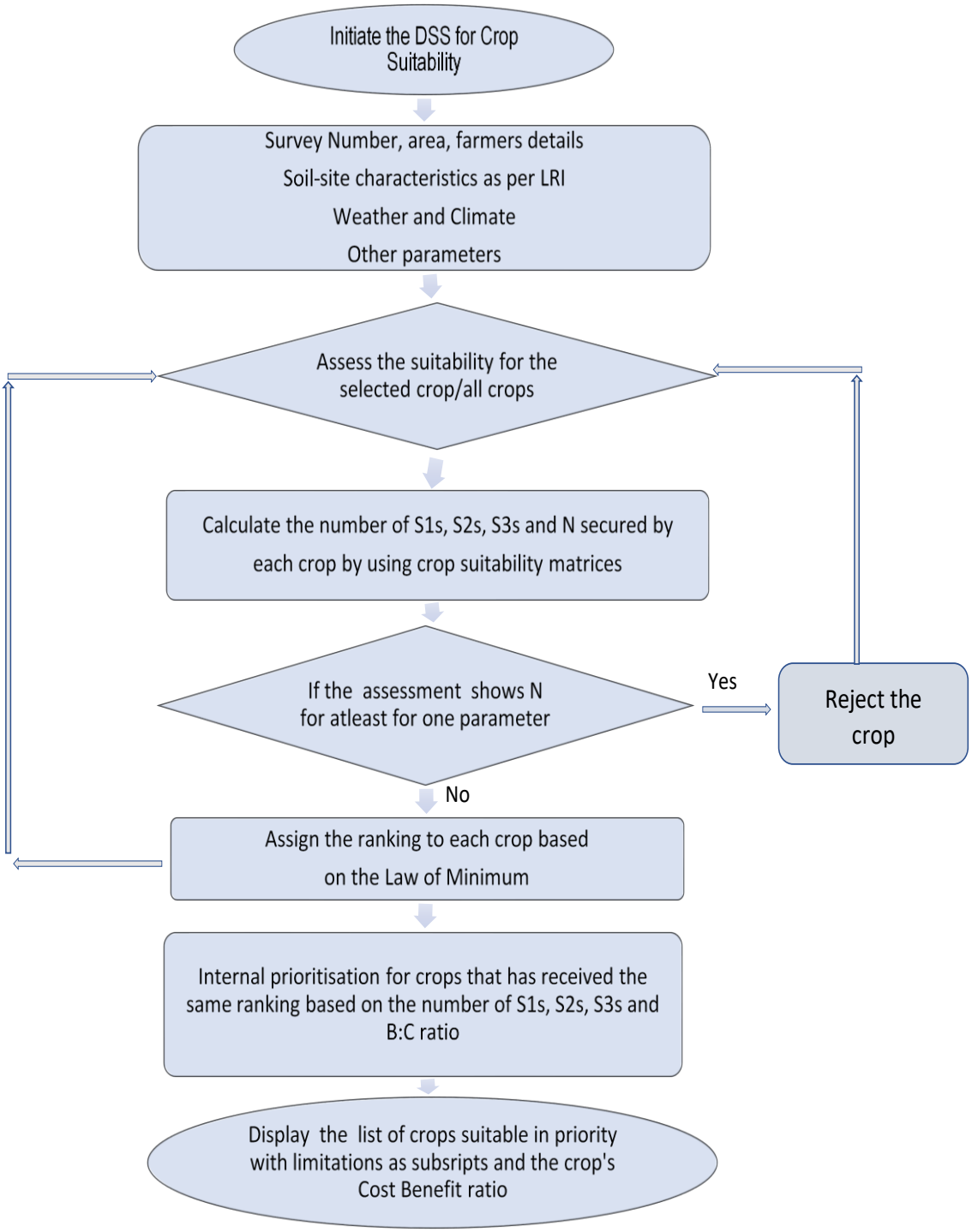


Figure 3.2 Flow chart for crop selection as provided in the FRS

Outputs and Reports expected from the DSS on Land Suitability

1. Survey number wise crop suitability for major crops cultivated in the **Parcel or Survey number**

Survey number	Farmer	Area	Season	Crop	Suitability class	Limitations	B: C Ratio	Overall rank	POP

Note: The column on farmer can be replaced with another table indicating only farmer details within each Survey number

- User should be able to select crop name, season and micro/sub watershed so that the thematic map of a selected watershed should be displayed for a given crop.
- Following report will be displayed when user select micro/sub watershed, season. This report to be populated by aggregating the result of all survey numbers within selected watershed.

2. Display of suitability maps for the major crops cultivated at **MWS and SWS levels**

MWS Name/code	Season	Major crops	Suitability class	Area under each class	Limitations	POP
1	Kharif	1	S1			
			S2			
			S3			
			NS			
		2				
		3				
		4				
		5				
	Rabi	1				
		2				
		3				
		4				
	Summer	1				
2		2				

The finalized soil-site suitability matrices for crop selection are as follows:

Land suitability criteria for Field Crops

Table 3.3 Land suitability criteria for **Irrigated Paddy**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temp. in growing season	°C	30-34	35-38 21-29	39-40 15-20	>40 <15
	Mean max. in growing season	°C				
	Mean min. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm	1000-1250	900-1000	750-900	<750
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Imperfectly drained	Moderately drained	W.D;somewhat ex. drained	Excessively drained
	Depth of water	cm	<10	10-20	>20-40	>40
Nutrient availability	Texture	Class	c,sic,cl,sicl,sc	scl, sil,l	sl, ls	s
	pH	1:2.5	5.5-6.5	6.4-7.5 4.5-5.4	7.6-8.5	>8.5 <4.5
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%	<15	15-25	25-30	>30
	OC	%				
Rooting conditions	Eff. soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	ds/m	<3	3-6	6-10	>10
	Sodicity (ESP)	%	<15	15-40	40-50	>50
Erosion hazard	Slope	%	0-1	1-3	3-5	>5

Note: Based on the suggestions/inputs received from project partners some of the parameter values given in the FRS document are changed later.

3.4 Land suitability criteria for **Upland paddy**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	Length of growing period for short duration	Days				
	Length of growing period for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well to mod. drained	poorly	Very poorly	-
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	cl, sc, c (red)	scl, c black)	ls, sl	-
	pH	1:2.5	5.5-6.5	6.5-7.3 5.0-5.5	7.3-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	-	3-5	>5

3.5 Land suitability criteria for **Maize**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	30-34	35-38 26-30	38-40 26-20	
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration		Yet to be finalised			
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc	c (red), c (black)	ls, sl	-
	pH	1:2.5	5.5-7.8	5.0-5.5 7.8-9.0	>9.0	-
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	-
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

3.6 Land suitability criteria for **Sorghum**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	26–30	30–34; 24–26	34–40; 20–24	>40; <20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, c red), c (black)	scl, cl	ls, sl	-
	pH	1:2.5	5.5-7.8	5.0-5.5 7.8-9.0	>9.0	-
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	10-15
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

3.7 Land suitability criteria for **Bajra (Pearl millet)**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-32	33-38 24-27	39-40 20-23	<20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm	500-750	400-500	200-400	<200
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	Length of growing period for short duration	Days				
	Length of growing period for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, scl, cl,sc,c (red)	c (black)	ls	-
	pH	1:2.5	6.0-7.8	5.0-5.5 7.8-9.0	5.5-6.0 >9.0	
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	15-35	35-60	>60	
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion	Slope	%	1-3	3-5	5-10	>10

3.8 Land suitability criteria for **Finger millet**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temp. in growing season	°C	28–34	25–28 34–38	38–40 20–25	>40 <20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well to moderately	Imperfectly drained-	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, scl, cl, sc, c (red)	-	c (black), ls	-
	pH	1:2.5	5.5-7.3	5.0-5.5 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.9 Land suitability criteria for **Fodder sorghum**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	26–30	30–34; 24–26	34–40; 20–24	>40; <20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	Length of growing period for short duration	Days				
	Length of growing period for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, c (red), c (black)	scl, cl	ls, sl	-
	pH	1:2.5	5.5-7.8	5.0-5.5 7.8-9.0	>9.0	-
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.10: *Land suitability criteria for* ***Minor millets***

Land use requirement			Rating			
		Unit	Highly suitable S1	Moderate-ly suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	28-34	28-25 34-38	25-20 38-40	<20 >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP	Days	>90	70-90	50-70	<50
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well-drained	Mod. Well drained, Imperfectly drained	Poorly drained	V. Poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, l, sil, scl, cl	sc, sic, sicl	ls, c	s
	pH	1:2.5	6.-0-8.0	8.0-8.5 6.0-5.0	8.5-9.0 5.0-4.0	>9.5 <4.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%				
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Crusting		Nil	Slight	Moderate	
	Coarse fragments	Vol %	<15	15-35	>35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	2.0-4.0	>4
	Sodicity (ESP)	%	<10	10-15	15-25	>25
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.11 Land suitability criteria for **Wheat**

Land use requirement			Rating			
		Unit	Highly suitable S1	Modera-tely suitable S2	Margin-ally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	20–25	25–28; 18–20	28–34; 16–18	<16 >34 <14
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP	Days	>150	120–150	90–120	<90
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained, moderately well drained	imperfectly drained	Poorly drained	v.poorly drained; excessive ly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	l, cl, sil, scl,	sc, sic,c, sicl, sl	Clayey soil (45 to 60% clay)	s & very fine clay >60%)
	pH	1:2.5	6.5–7.5	7.6–8.5; 5.5–6.4	8.6-10; 4.5–5.4	<4.5 >10
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%				
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50–75	25–50	<25
	Stoniness	%	<15	15–35	>35	
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	ds/m	<4.0	4.0–6.0	> 6.0	
	Sodicity (ESP)	%	<15	15–30	30–40	>40
Erosion hazard	Slope	%	<3	3–<5	5–10	>10

* Note - C+ = Clay (45-60%), C++ = Clay > 60%

Land suitability criteria for Pulses

Table 3.12 Land suitability criteria for **Red gram**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	30-35(G) 20-25(AV) 15-18 (F&PS) 35-40(M)	25-30(G) 20-25 (AV) 12-15 (F&PS) 30-35(M)	20-25(G) 15-20(AV) 10-12 (F&PS) 25-30(M)	< 20 <15 <10 <25
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration crop	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	V.Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, c (red)	c (black),sl, scl, cl	ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-9.0	5.0-5.5 >9.0	-
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.13 Land suitability criteria for **Bengal gram**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	20–25	25–30; 15–20	30–35; 10–15	>35; <10
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	Length of growing period for short duration	Days				
	Length of growing period for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	C (black)	-	c (red), scl, cl, sc	ls, sl
	pH	1:2.5	6.0-7.8	5.0-6.0 7.8-9.0	>9.0	-
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	-
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.14 Land suitability criteria for **Field bean**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	20-35	18-20 35-40	15-18 40-45	<15 >45
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	c (red), sl, scl, cl, sc	c (black)	ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.15 Land suitability criteria for **Horse gram**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	c (red), sl, scl,cl	c (black)	ls	-
	pH	1:2.5	5.5-7.8	5.0-5.5 7.8-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>50	25-50	<25	-
	Stoniness	%				
	Coarse fragments	Vol %	<35	-	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	-
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.16 Land suitability criteria for **Cluster beans**

Land use requirement			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	24-33	22-24 33-35	20-22 35-40	<20 >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP	Days	>110	90-110	60-90	<60
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained/ mod. Well drained	Imperfectly drained	Poorly drained	V. Poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, l, scl, cl, sc	sic, sicl c,ls	Heavy clays	-
	pH	1:2.5	6.-0-8.0	8.0-8.5 5.5-6.0	8.5-9.5 4.0-5.5	>9.5 <4.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%	<15	15-25	25-30	>30
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stonnines	%				
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	2.0-4.0	>4
	Sodicity (ESP)	%	<10	10-15	15-20	>20
Erosion hazard	Slope	%	<5	5-10	10-15	>15

Land suitability criteria for Oilseed Crops

Table 3.17 Crop suitability criteria for **Sunflower**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	24–30	30–34; 20–24	34–38; 16–20	>38; <16
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	mod. Well drained	Imperfectly drained	Poorly to v.p drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	cl, sc,c (red), c (black)	scl	ls, sl	-
	pH	1:2.5	6.5-7.8	7.8-8.4 5.5-6.5	8.4-9.0; 5.0-5.5	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.18 Crop suitability criteria for **Groundnut**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	24–33	22–24; 33–35	20–22; 35–40	<20; >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl	sl,cl, sc	c (red), c (black), ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<35	35-60	>60	
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.19 Crop suitability criteria for **Soybean**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	25-28	28-32	32-34	>34
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well drained	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc,c (red), c (black)	sl	ls	-
	pH	1:2.5	6.5-7.8	6.0-6.5 7.8-8.4	5.0-6.0 8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.20 Land suitability criteria for **Castor**

Land use requirement			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	26-32	32-35 24-26	35-40 20-24	>40 <15
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for varieties	Early	>120	90-120	<90	
		Medium	>150	120-150	90-120	
		Late	>210	180-210	150-180	
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well.drained	Imp. drained	Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	l, scl, sil, cl sl	sicl, sic, sc, c(m+k)	ls, c(s)	s
	pH	1:2.5	6.5-7.5	6.5-5.0 7.5-8.0	8.0-9.0 4.0-5.0	>9.0 <4.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%	Non calcareous	<5	5-10	>10
	OC	%	Medium	High	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stonnines	%				
	Coarse fragments	Vol %	Non gravelly	<15	15-35	>35
Soil toxicity	Salinity (EC saturation extract)	ds/m	Non saline	1.0-2.0	2.0-4.0	>4.0
	Sodicity (ESP)	%	Non-sodic	10-15	15-20	>20
Erosion hazard	Slope	%	<3	3-5	5-10	

Mineralogy: C (m+k) clay (mixed/kaolinitic), C(s) = (smectitic)

Table 3.21 Land suitability criteria for **Sesame**

Land use requirement			Rating			
		Unit	Highly suitable S1	Mod. suitable S2	Mar. suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	30-34	30-25 34-38	25-20 38-40	<20 >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for varieties	Early	>90	70-90	60-70	<60
		Medium	>120	90-120	70-90	<70
		Late	>150	120-150	90-120	<90
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well drained	Imp. to poorly drained	Very poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	,scl,l, sil, cl, sl	sicl, sc c(red soils)	ls, c (black soils)	s
	pH	1:2.5	5.5-7.5	7.5-8.0 5.0-5.5	8.0-9.0 4.9-4.5	<4.5 >9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%				
	OC	%	High	Medium	Low	
Rooting conditions	Effective soil depth	cm	>75	50-75	50-25	<25
	Stonnines	%	<15	15-35	25-35	>35
	Coarse fragments	Vol %				
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	2.0-4.0	>4.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Land suitability criteria for Commercial Crops

Table 3.22 Land suitability criteria for **Cotton**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Mar.suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	22-32	>32	<19	-
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP period for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well to moderately well	P.drained/Somewhat ex. drained	-	v.poorly/excessively drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, c (red,black)	cl	scl	ls, sl
	pH	1:2.5	6.5-7.8	7.8-8.4	5.5-6.5 8.4->9.0	<5.5
	CEC	C mol (p+)Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	50-100	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	5-10	10-15	>15	
Erosion hazard	Slope	%	<3	3-5	-	>5

Table 3.23 Land suitability criteria for **Sugarcane**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Mod.suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	30-34 10-20	26-30/ 34-38 20-30	26-20/38-40 10-5	<20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well drained	P.drained/somewhat ex. drained	V.poorly/ excessively drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	cl, sc,	scl, c(red)	sl, c(black)	ls
	pH	1:2.5	6.5-7.8	6.0-6.5 7.8-8.4	5.0-6.0 8.4-9.0	<5.0 >9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	-	>5

Table 3.24 Land suitability criteria for **Chillies**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	25-32	33-35 20-25	35-38 <20	>38
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	Very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc	c (black), sl	ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.25 Land suitability criteria for **Turmeric**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-32	20-27 33-37	10-19 38-40	<10 >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well drained	-	Poorly to very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl,scl, cl	sc	ls, c (red), c (black)	-
	pH	1:2.5	5.5-6.5	5.0-5.5 6.5-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.26 Land suitability criteria for **Tamarind**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well drained	Poorly drained	V.Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl,sc, c (red)	sl, c (black)	ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>150	100-150	75-100	<75
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.27 Land suitability criteria for **Mulberry**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	24–28	22–24; 28–32	32–38; 22–18	>38; <18
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V. Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, cl, scl	c (red)	c (black), sl, ls	-
	pH	1:2.5	5.5-7.3	5.0-5.5 7.8-8.4	7.3-8.4	>8.4
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<35	35-60	60-80	>80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.28 Land suitability criteria for (F.C.V) **Tobacco**

Land use requirement			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Mar. suitable S3	Not suitable N
Climatic regime	Mean temperature in growing season	°C	26-30	31-34 21-25	35-40 <20	>40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%	70-80	70-60,>80	60-50	<50
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP	Days	>120	100-120	90-100	<90
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. to imp.drained	Poorly	Very poorly
	Water logging	Days	<24	24-48	48-72	>72
Nutrient availability	Texture	Class	sl, sil, scl,	cl, Sc, Sic,	C, S, ls, C(s)	
	pH	1:2.5	5.5 o 6.5	6.5-8.5	8.5-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%	Nil Nil	Upto 5 <0.01	5-10 0.01	>10 >0.01
	OC	%				
Rooting conditions	Effective soil depth	cm	100	50-100	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	Nongravelly	Upto 15	15-35	>35
Soil toxicity	Salinity (EC saturation extract)	ds/m	Non saline	0.5-1.0	1.0-1.5	>1.5
	Sodicity (ESP)	%	Non sodic			
Erosion hazard	Slope	%	<3	3-5	5-10	>10
Leaf quality	Soil types/soil mineralogy		Red/lateritic ,Mixed/kaolinitic	Alluvial Illitic	Shrink swell, Clay	

Land suitability criteria for plantation crops

Table 3.29 Land suitability criteria for **Coconut**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	26–29	23–25; 30–32	20–22; 32–34	
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. to Poorly drained	-	Very poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl,cl,	sl, c (red)	ls, c (black)	-
	pH	1:2.5	5.0-7.3	7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.30 Land suitability criteria for **Areca nut**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	25–30	22–25; 30–32	20–22; 32–36	
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. to poorly drained	-	Very poorly
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc	c (red), sl	c (black),ls	-
	pH	1:2.5	5.0-7.3	7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.31 Land suitability criteria for **Cashew**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	32 to 34	28 to 32; 34 to 38	24 to 28; 38 to 40	<20; >40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	moderately well drained	Poorly drained	Very poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	-	sl, ls	c (black)
	pH	1:2.5	5.5-6.5	5.0-5.5 6.5-7.3	7.3-7.8	>7.8
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-10	>10	-

VI Land suitability criteria for fruit crops

Table 3.32 Land suitability criteria for **Mango**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-32	24-27 33-35	36-40	20-24
	Min temp. before flowering	^{0}C	10-15	15-22	>22	-
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration	Days				
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	-	ls, sl, c (black)	-
	pH	1:2.5	5.5-7.3	5.0-5.5 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Eff. soil depth	cm	>150	100-150	75-100	<75
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.33 Land suitability criteria for **Pomegranate**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	30-34	35-38 25-29	39-40 15-24	
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl,cl, sc, c (red)	c (black),sl	ls	-
	pH	1:2.5	5.5-7.8	7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 334 Land suitability criteria for **Guava**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-32	33-36 24-27	37-42 20-23	
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	sl	c (black), ls	-
	pH	1:2.5	6.0-7.8	5.0-6.0	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.35 Land suitability criteria for **Sapota**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-32	33-36 24-27	37-42 20-23	>42 <18
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	-	Poorly to very drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	sl	ls, c (black)	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.36 Land suitability criteria for **Banana**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	26-33	34-36 24-25	37-38	>38
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red), c (black)	sl	ls	-
	pH	1:2.5	6.0-7.3	5.5-6.0 7.3-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1-2	2-4	>4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.37 Land suitability criteria for **Lime**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-30	31-35 24-27	36-40 20-23	>40 <20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP- short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately drained	poorly	Very poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c	sl	ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.38 Land suitability criteria for **Musambi**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	28-30	31-35 24-27	36-40 20-23	>40 <20
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately drained	poorly	Very poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c	sl	ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.39 Land suitability criteria for **Jackfruit**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well	Poorly	V. Poorly
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	-	sl, ls, c (black)	-
	pH	1:2.5	5.5-7.3	5.0-5.5 7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10-

Table 3.40 Land suitability criteria for **Jamun**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well	Mod. well	Poorly	V.Poorly
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c(red)	sl, c (black)	ls	-
	pH	1:2.5	6.0-7.8	5.0-6.0	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>150	100-150	50-100	<50
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.41 Land suitability criteria for **Amla**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well drained	Poorly drained	V. Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	c (black)	ls, sl	-
	pH	1:2.5	5.5-7.3	5.0-5.5 7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15-35	35-60	60-80	-
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	5-10	>10

Table 3.42 Land suitability criteria for **Custard apple**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	Scl, cl, sc, c (red), c (black)	-	Sl, ls	-
	pH	1:2.5	6.0-7.3	5.5-6.0 7.3-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15-35	35-60	60-80	-
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	0-3	3-5	>5	-

Land suitability criteria for vegetables

Table 3.43 Land suitability criteria for **Onion**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temp. in growing season	°C	20-30	30-35	35-40	>40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately /imperfectly	-	Poorly to v.p drained
	Water logging	Days				
Nutrient availability	Texture	Class	sl,scl,cl,sc,c (red)	-	c (Black),ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	$CaCO_3$- root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Eff. soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	2.0-4.0	<4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.44 Land suitability criteria for **Tomato**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	25-28	29-32 20-24	15-19 33-36	<15 >36
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LPG for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, scl, cl, sc, c (red)	-	ls, c(black)	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.45 Land suitability criteria for **Cabbage**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	15-25	26-30	31-35 10-14	>35 <10
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl,scl,cl,sc, c (red)	-	ls, c (black)	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.46 Land suitability criteria for **Bhendi**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	25-28	29-32 20-24	15-19 33-36	<15 >36
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poorly to very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl,sc, c (red)	c (black)	ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.47 Land suitability criteria for **Drumstick**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sc, scl, cl, c (red)	sl, c (black)	ls	s
	pH	1:2.5	6.0-7.3	5.0-5.5 7.3-7.8	5.5-6.0 7.8-8.4	>8.4
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>100	75-100	50-75	<50
	Stoniness	%				
	Coarse fragments	Vol %	<35	35-60	60-80	>80
Soil toxicity	Salinity (EC saturation extract)	ds/m				
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-10	-	>10

Table 3.48 Land suitability criteria for **Brinjal**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	Well drained	Moderately well drained	Poorly drained	V. Poorly drained
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class				
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl, scl, cl, sc c (red)	-	ls, c (black)	-
	pH	1:2.5	6.0-7.3	7.3-8.4 5.0-6.0	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	>60
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.49 Land suitability criteria for **French bean**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod. Well drained	Poorly drained	Very Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	c (red), sl, scl, cl, sc	c (black)	ls	-
	pH	1:2.5	6.0-7.8	5.5-6.0 7.8-8.4	5.0-5.5 8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	>2.0	
	Sodicity (ESP)	%	<10	10-15	15-20	>20
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.50 Land suitability criteria for **Beetroot**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temp. in growing season	°C	20-30	30-35	35-40	>40
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately /imperfectly	-	Poorly to v.poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl,scl,cl,sc,c (red)	-	c (Black),ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Eff. soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<1.0	1.0-2.0	2.0-4.0	>4
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.51 Land suitability criteria for **Potato**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	16-25	26-30 13-15	31-32 10-12	>32 <10
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP- short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	-	Poorly to very poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	scl, cl,sl, sc	ls (red)	s, c (black)	-
	pH	1:2.5	5.5-6.5	5.0-5.5 6.5-7.8	7.8-8.4	>8.4
	CEC	C mol (p+)/ Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%				
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Land suitability criteria for flower crops

Table 3.52 Land suitability criteria for **Marigold**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	18-23	17-15 24-35	35-40 10-14	>40 <10
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging in growing season	Days				
Nutrient availability	Texture	Class	sl,scl, cl, sc, c (red)	c (black)	ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Eff. soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%				
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.53 Land suitability criteria for **Chrysanthemum**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	18-23	17-15 24-35	35-40 10-14	>40 <10
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	sl,scl, cl, sc, c (red)	c (black)	ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%				
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.54 Land suitability criteria for **Jasmine (irrigated)**

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C	18-23	17-15 24-35	35-40 10-14	-
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	V.Poorly drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c (red)	sl	ls, c (black)	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity (EC saturation extract)	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%				
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Table 3.55 Land suitability criteria for **Crossandra**

Land use requirement			**Rating**			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime	Mean temperature in growing season	°C				
	Mean max. temp. in growing season	°C				
	Mean min. tempt. in growing season	°C				
	Mean RH in growing season	%				
	Total rainfall	mm				
	Rainfall in growing season	mm				
Land quality	Soil-site characteristic					
Moisture availability	LGP for short duration	Days				
	LGP for long duration					
	AWC	mm/m				
Oxygen availability to roots	Soil drainage	Class	Well drained	Mod.well drained	-	Poorly to v.p. drained
	Water logging	Days				
Nutrient availability	Texture	Class	scl, cl, sc, c(red)	sl,	c (black),ls	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CEC	C mol (p+)/Kg				
	BS	%				
	CaCO3 in root zone	%		<5	5-10	>10
	OC	%				
Rooting conditions	Effective soil depth	cm	>75	50-75	25-50	<25
	Stoniness	%				
	Coarse fragments	Vol %	<15	15-35	35-60	60-80
Soil toxicity	Salinity	ds/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%				
Erosion hazard	Slope	%	<3	3-5	5-10	>10

Note: Criteria for additional crops can be added as and when it is developed by NBSS and LRI partners with inputs from respective departments concerned. Apart from this, the refinement of the criteria will be an ongoing exercise.

Chapter 4

DSS for delineating arable and prime farmlands in the project districts (based on land capability assessment)

Land capability assessment is done to find out the general capability of the resources of an area for agricultural crops, forestry and other uses. In this assessment, the mapping units occurring in an area are grouped according to their limitations they pose for cultivation, the risk of damage if they are used for the identified use, and the way they respond to management interventions. Normally the criteria used in grouping the units do not take into consideration any major and costly reclamation measures or conservation techniques that change the slope, depth or characteristics of the soils. This system is not aimed to find out the suitability of the land resources for specific uses or crops. Though the classification was evolved originally to help the soil conservation efforts, but now this system can be used for identifying priority areas, which requires immediate attention and development within a watershed or project areas.

The capability grouping is based on the inherent soil characteristics, external land features and environmental factors that limit the use of the land for different purposes (I.A.R.I., 1971 and Soil Survey Division Staff, 1993). The following land and soil characteristics are used to group the land resources identified in an area into various classes, subclasses and units.

- Soil characteristics: Soil depth, texture, gravelliness, soil reaction, water holding capacity, calcareousness, salinity/ alkalinity etc.
- Land features: Slope, erosion, rock outcrops and drainage.
- Climate: Rainfall distribution and length of growing period.

In the capability system, mapping units are generally grouped at three levels – capability class, subclass and unit. Depending on the level of available information, grouping can be done at any one of the above levels. If the information available for an area is of general nature, then the classification can be done only up to class or subclass level and if it is detailed and site-specific then the classification can be done up to the unit level, which is an equivalent of a management unit for the survey area. Since site-specific and comprehensive database is generated through the Land Resource Inventory for all the watersheds in the project districts, the land resources can be grouped into various land capability units for each watershed area.

Structure of the classification

Capability classes, the broadest groups, are designated by roman numerals I to VIII. The numerals indicate progressively greater limitations and narrow choices for practical use. The classes I to IV are arable lands and classes V to VIII are non-arable lands. The eight classes used in the classification are:

Class I	The mapping units have few or very few limitations that restrict their use.
Class II	Mapping units have moderate limitations that reduce the choice of the crops or that require moderate conservation practices.
Class III	Mapping units have severe limitations that reduce the choice of the crops or that require special conservation practice, or both.
Class IV	Mapping units have very severe limitations that reduce the choice of the crops or that require very careful management, or both.
Class V	Soils in the mapping units are not likely to erode, but they have other limitations, impractical to remove that limit their use.
Class VI	The land area has severe limitations that make them generally unsuitable for cultivation.
Class VII	The land area has very severe limitations that make them unsuitable for cultivation.
Class VIII	Soils and miscellaneous areas have limitations that nearly preclude their use for any commercial crop production

Capability subclasses are formed based on the dominant limitations observed within the capability class. They are designated by adding a lower-case letter like **e, w, s, or c,** to the class numeral. For example, in subclass IVe, the letter 'e' shows that the main hazard in class IV land is the risk of erosion. Similarly, the symbol 'w' indicates drainage or wetness as a limitation for plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); the symbol 's' indicates shallow depth, calcareousness, salinity and sodicity or gravelly nature of soil as limitations and 'c' indicates climate or rainfall with short growing period as a limitation for plant growth.

The land capability subclasses have been divided into land capability units based on the kinds of limitations present. Ten land capability subclass units are used in grouping the resources of an area, which are indicated below with their symbols

(0) Stony or rocky
(1) Erosion hazard (slope, erosion)
(2) Coarse textures (sand, loamy sand, sandy loam)
(3) Fine texture (cracking clay, silty clay)
(4) Slowly permeable sub soils
(5) Coarse underlying material
(6) Salinity or alkali
(7) Stagnation, overflow, high groundwater
(8) Soil depth
(9) Fertility problems

Capability units have almost similar soil and other land characteristics that influence the use of the land resources at the field level. Accordingly, each capability unit is expected to respond uniformly to a given level management. (Note: Under Sujala III project, land capability assessment is done only up to land capability subclass and not up to land capability unit levels)

By following the Land capability classification system, the phases mapped, or the map units identified at the watershed level can be grouped into various land capability classes, sub classes and land capability units. The various parameters to be considered and their ratings to be used in grouping the land parcels/areas into land capability units are given in the table below.

Source:

1. United States Department of Agriculture (USDA), 2012, Soil Survey Manual, Handbook No:18, USDA, USA.
2. Natarajan, A., and Dipak Sarkar, 2010, Field guide for soil survey, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), ICAR, Nagpur, India.
3. IARI (1971) Soil Survey Manual, IARI, New Delhi

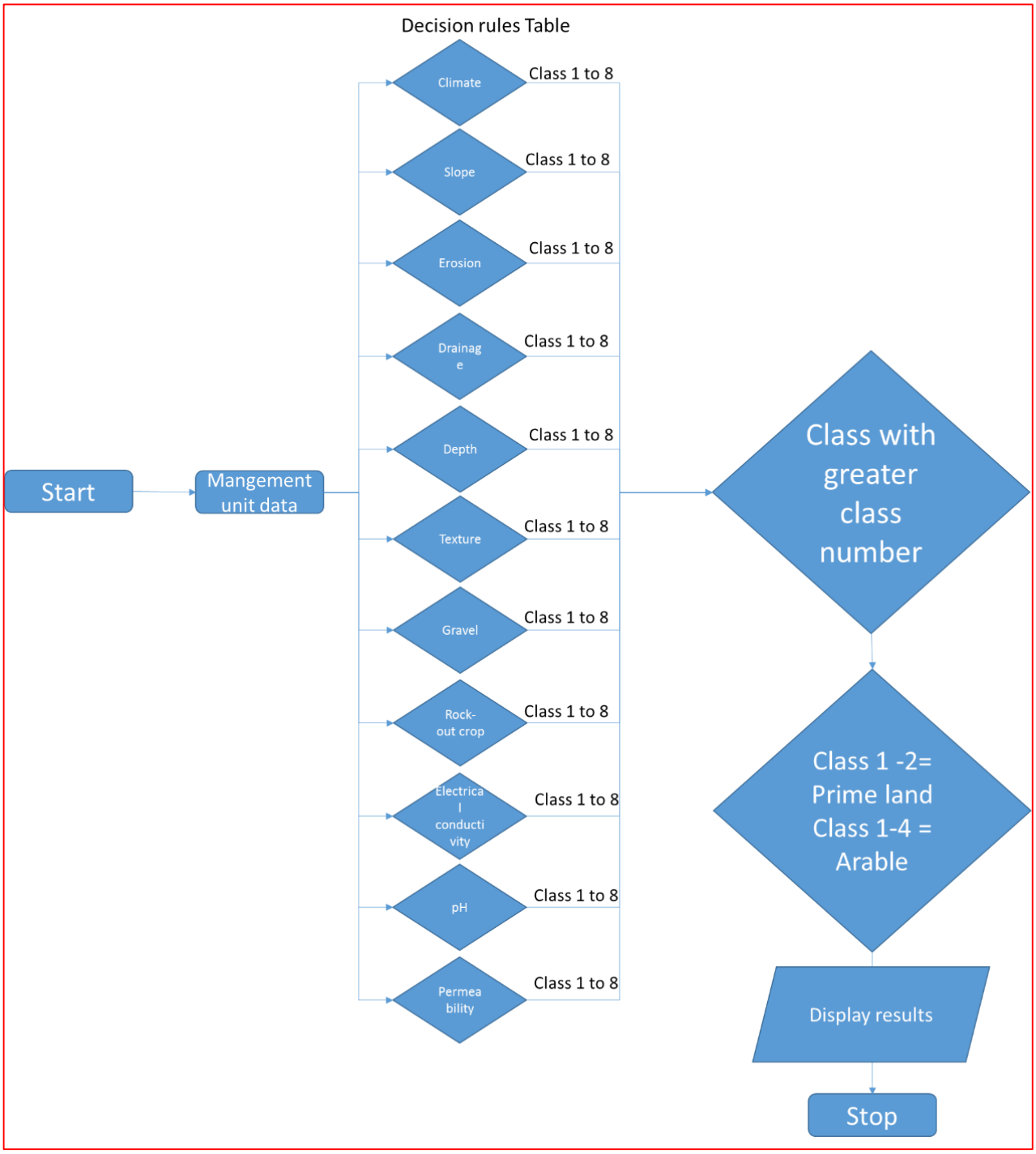
Table 4.1 Parameters and their ratings to be used for land capability units/classes

Climate, soil and site parameters/features affecting LCC		Land capability ratings							
		Suitable for Agriculture				Suitable for forestry, sylvipasture, wildlife etc.			
		Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII	Class VIII
Climate	Humid with well distributed rainfall	√							
	Humid with occasional dry spells		√						
	Sub humid-yields frequently reduced by droughts		√						
	Semi-arid			√					
	Arid				√				
Slope	**Red soils**								
	A (<1%)	√							
	B (1-3%)		√						

	C (3-5%)		√						
	D (5-10%)			√					
	E&F (10-25%)				√				
	G,H&I (25>50%)						√		
	Black soils								
	A (<1%)	√							
	B (1-3%)		√						
	C (3-5%)			√					
	D (5-10%)				√				
Erosion	Slight (e_1)	√							
	Moderate (e_2)		√						
	Severe (e_3)			√					
	Very Severe (e_4)				√				
Drainage	Excessive						√		
	Well drained	√							
	Mod.WD		√						
	Imperfect			√					
	Poor				√				
	Very Poor					√			
Soil depth	> 100 cm	√							
	50 –100 cm		√						
	25-50 cm			√					
	10-25 cm				√				
	< 10 cm						√		
Texture	sl, scl, cl, loam, silty clay loam	√							
	sandy clay, silty clay		√						
	clay			√					
	loamy sand				√				
	sand						√		
Gravels	< 15 %	√							
	15-35 %		√						

	35-60 %			√					
	> 60 %				√				
Rockout crops (%)	<2		√						
	2-10			√					
	10-50				√				
	50-90						√		
	>90								√
Salinity EC	<2	√							
	2-4		√						
	4-8			√					
	8-16				√				
pH	Favorable Reaction (6.5-7.5)	√							
	Unfavourable reaction (easy to modify) (5.56.5 & 7.5-8.5)		√						
	Unfavourable reaction (difficult to modify) (4.55.54& 8.5-9.5)			√					
	Unfavourable reaction (exceedingly difficult to modify) (<4.5&>9.5)				√				
Permeability	Very slow			√					
	Slow		√						
	Mod. slow	√							
	rapid			√					
	Very rapid							√	

Note: While assigning the land capability class for any unit based on soil and other land features, the property that acts as a major limiting factor for production is given importance.



Note: Management unit refers to the **Soil phase** as mapped under LRI

Figure 4.1: Flow diagram for delineating prime farmlands as provided in the FRS

Module Description for the execution of the DSS on Land Capability

After successful login, user will click on 'Land Capability Classification' under Decision Support System. A web page for Land Capability Classification DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number. The details of input fields in Web page are as mentioned in section. "From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will auto fill the District, Taluk, Village and Survey number values.
- User will select the District, Taluk, Village, Micro Watershed and Survey number.
- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- A query will be executed to find the Slope, Erosion, Drainage, Soil depth, Texture, Rock out Crops, EC, pH, Permeability from Parcel Characteristic table for the respective cadastral id.
- A query will be executed on climate data to find the climate condition for the respective area.
- Execute the query on Master_Land_capability Table to find
    - Class for Climate category against Climate value.
    - Class for Slope category against the slope value.
    - Class for Erosion category against Erosion value.
    - Class for Drainage category against Drainage value.
    - Class for Soil Depth category against Depth value.
    - Class for Soil Texture category against Texture value.
    - Class for Gravels category against Gravel value.
    - Class for Rock out crops category against Rock out crops value.
    - Class for EC category against EC Value.
    - Class for pH category against pH Value.
    - Class for Permeability category against Permeability Value.
- If for all Class Value comes as 'I' then update the LCC as 'I".
- If any class value is greater than 'I", Get highest class value from all above for deciding the LCC. And add the lower-case letter like e, w, s, or c to the Class number. e.g, IIIw, the letter 'w' shows that the drainage or wetness is limitation in class III land.

  Below symbols will be used to show the limitations
    - e – Erosion limitation
    - w – Drainage Limitation
    - s - Depth, Texture, gravel, rockout crop, EC,pH, Permeability limitation
    - c – Climate Limitation
- Save the result in Land Capability Table with Id, Cadastral ID, LCC, Limitation.

- Display the result in a table showing the information such as Survey number, farmer Name, area in hectare, Land Capability Classification, Limitation, Arable/Non-Arable.
- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyse DSS results based on these temporary changes.

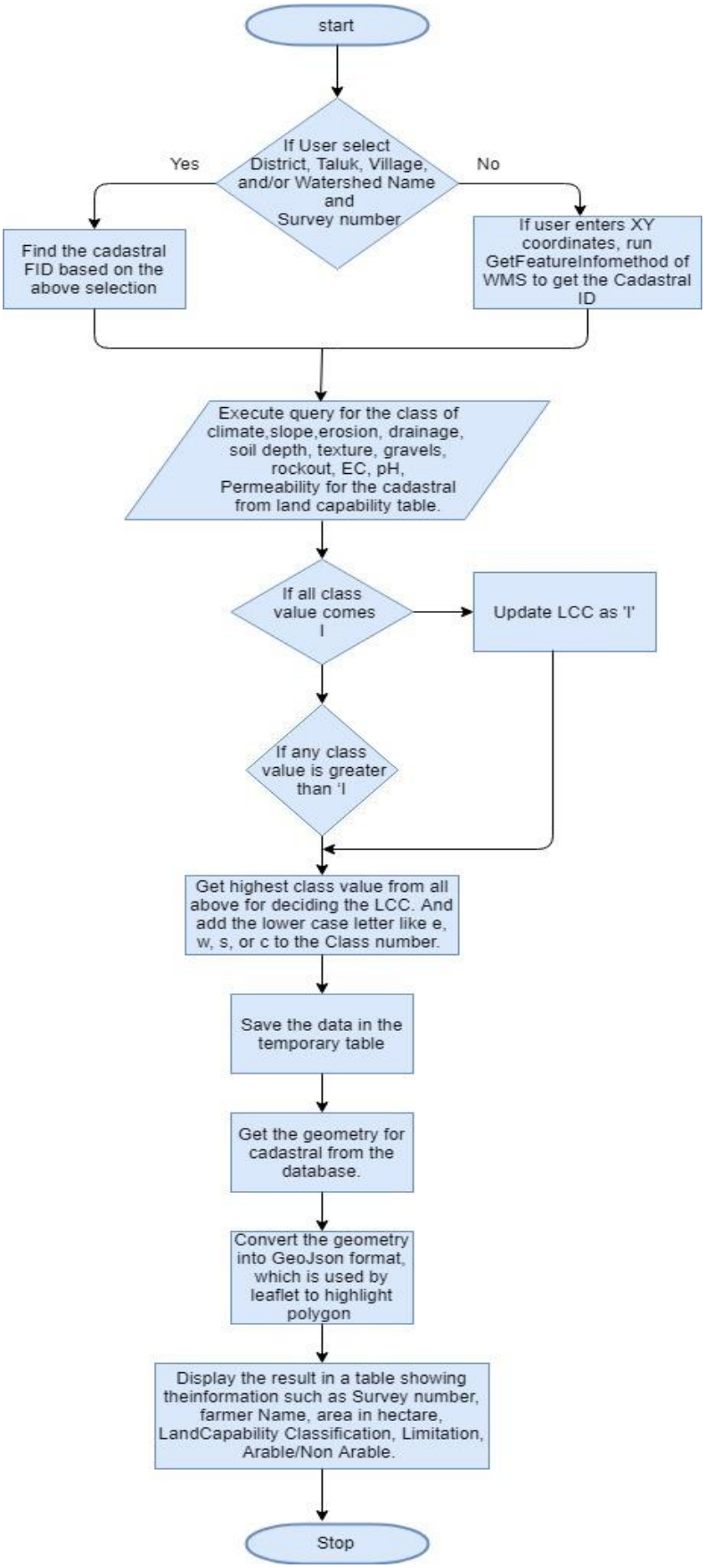


Fig.4.2 Flow chart for the execution of the DSS on Land Capability as per LLDD

Outputs and reports from the DSS on Land Capability

1. **Survey number wise land capability** with limitations and measures to overcome the same

Survey number	~~Farmer~~	Area	Arable area				Non arable				Limitations	Conservation/ land use suggestions
			I	II	III	IV	V	VI	VII	VIII		

Farmer details will be provided in a separate table

2. Display of Land capability maps and area under each capability class at MWS/SWS levels

MWS Name/ code	~~Soil unit~~	Land capability class								Area under each class	Limitations	Conservation/land use suggestions	Remarks
		I	II	III	IV	V	VI	VII	VIII				
1													
2													

DSS for Crop based Nutrient Management and Soil Health

To find out the fertility status of the soils, surface soil samples are collected during LRI at 250/325-meter grid intervals and analyzed for the soil fertility parameters like organic carbon, nitrogen, phosphorous, potassium, calcium, magnesium, Sulphur, copper, iron, zinc, manganese and boron.

The ratings used to group the soils into various classes are presented in Table 5.1 and 5.2. Based on the ratings fertility status maps for the Micro watersheds covered under Sujala III project are generated and distributed to the users. The fertility status maps, and the ratings are used to arrive NPK and micronutrient recommendations.

Inputs data required for the DSS: GIS layers of all soil fertility parameters, crop wise NPK fertilizer and micronutrient recommendations, criteria for adjusting the fertilizer recommendations, information of the farmer and location details of the farmer's field.

Table 5.1 Soil fertility classes based on content of macro nutrients (kg/ha)

Nutrient	Very Low	Low	Medium	High	Very High
Organic Carbon (gKg^{-1})	<0.25	< 0.25 to 0.49	0.50 to 0.75	0.76 to 1.00	>1.00
Available N	<140	140 to 280	281 to 560	561 to 700	>700
Available P_2O_5 (P x 2.29)	<11.45	11.45 to 22.90	22.91 to 57.25	57.26 to 91.60	>91.60
Available K^2O (K x1.2)	<72.3	72.3 to 144.6	144.7 to 337.4	337.5 to 674.8	>674.8

Table 5.2 Critical limits of micronutrients in soils

Nutrient	Critical level	Deficient/low	Sufficient
Available Cu (ppm)	0.2	<0.2	>0.2
Available Zn (ppm)	0.6	<0.6	>0.6
Available Mn (ppm)	2.0	<2	>2
Available Fe (ppm)	4.5	<4.5	>4.5
Available Boron (ppm)	0.5	<0.5	>0.5
Available S (mgKg-1)	10	<10	>10

Table 5.3 (a) Crop wise fertilizer recommendation- For **Cereals and Pulses**

Fertilizer recommendation for crops																	
S. No	Crop	ACZ	Season	Dry/Irrigated	N	P_2O_5	K^2O	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ ha	Fe kg/ ha	B kg/ ha	S kg/ ha
1	Paddy	1,2	Kharif	Irrigated	100	50	50	50	50	50	50	0	0	4.1	0	0	0
2	Paddy	3	Kharif	Irrigated	100	75	63	75	75	38	25	0	25	4.1	0	0	0
3	Paddy	4,5,6,7,	Kharif	Irrigated	100	50	50	50	50	25	50	0	25	4.1	0	0	0
4	Paddy	8	Kharif	Irrigated	100	50	50	50	50	25	50	0	25	4.1	0	0	0
5	Paddy	9	Kharif	Irrigated	75	75	90	37	75	45	38	0	45	4.1	0	0	0
6	Paddy	10	Kharif	Irrigated	60	30	45	20	30	22	40	0	23	4.1	0	0	0
7	Paddy	4,5,6,7,8,9,	Kharif	Dry-rainfed	100	50	50	50	50	50	50	0	0	4.1	0	0	0
8	Paddy	1,2,3,4,5,6,7, 8,9	Summer	Irrigated	125	63	63	62	63	31	63	0	32	4.1	0	0	0
9	Paddy hybrid	4,5,6	Kharif	Irrigated	125	63	63	62	63	31	63	0	32	4.1	0	0	0
10	Paddy hybrid	4,5,6	Summer	Irrigated	158	80	80	79	80	40	79	0	40	4.1	0	0	0
11	Jowar	1	Kharif	Dry-rainfed	100	75	35	50	75	35	50	0	0	3.1	0	0	0
12	Jowar	2	Kharif	Dry-rainfed	60	40	40	30	40	40	30	0	0	3.1	0	0	0
13	Jowar	3	Kharif	Dry-rainfed	100	75	38	50	75	38	50	0	0	3.1	0	0	0
14	Jowar	4,5,6,7,	Kharif	Dry-rainfed	65	40	40	32	40	40	33	0	0	3.1	0	0	0
15	Jowar	8	Kharif	Dry-rainfed	100	75	26	50	75	13	50	0	13	3.1	0	0	0
16	Jowar	4,5,6,7,	Kharif	Irrigated	100	75	40	50	75	40	50	0	0	0	0	0	0
17	Jowar	1,2,3,8,	Rabi	Dry	100	75	38	50	75	38	50	0	0	3.1			
18	Jowar	4,5,6	Rabi	Dry	50	25	0	50	25	0		0	0	3.1	0	0	0
19	Jowar	1,2	Rabi	Irrigated	100	75	40	50	75	40	50	0	0	3.1	0	0	0
20	Jowar	3	Rabi	Irrigated	100	62	60	50	62	60	50	0	0	3.1	0	0	0

21	Jowar	8	Rabi	Irrigated	100	60	40	50	60	40	50	0	0	3.1	0	0	0
22	Jowar	4,5,6,7,	Summer	Irrigated	100	75	40	50	75	40	50	0	0	0	0	0	0
23	Jowar	8	Summer	Irrigated	100	75	40	50	75	40	50	0	0	0	0	0	0
24	Maize	3,8,	Kharif	Irrigated	150	65	65	15	65	65	135	0	0	5.1	4.8	0	0
25	Maize	3,8	Rabi	Irrigated	150	65	65	15	65	65	135	0	0	5.1	4.8	0	0
26	Maize	3,8,	Kharif	Dry	100	50	25	50	50	25	50	0	0	2.05	0	0	0
27	Maize	4,5,6,7,	Kharif	Irrigated	150	75	40	50	75	40	100	0	0	4.1	0	0	0
28	Maize	4,5,6,7	Kharif	Dry	100	50	25	50	50	25	50	0	0	4.1	0	0	0
29	Maize	4,5,6,7,	Rabi	Irrigated	150	75	40	50	75	40	100	0	0	4.1	0	0	0
30	Maize	4,5,6,7	Summer	Irrigated	150	75	40	50	75	40	100	0	0	4.1	0	0	0
31	Ragi	2,3,8	Kharif	Irrigated	100	50	50	50	50	50	50	0	0	0	0	0	0
32	Ragi	2,3,8	Summer	Irrigated	100	50	50	50	50	50	50	0	0	0	0	0	0
33	Ragi	2,3,8	Kharif	Dry	50	40	25	25	40	25	25	0	0	0	0	0	0
34	Ragi	4,5,6,7	Kharif	Irrigated	100	50	50	50	50	50	50	0	0	2.6	0	1.05	0
35	Ragi	4,5,6,7	Rabi	Irrigated	100	50	50	50	50	50	50	0	0	2.6	0	1.05	0
36	Ragi	4,5,6,7	Summer	Irrigated	100	50	50	50	50	50	50	0	0	2.6	0	1.05	0
37	Ragi	4,5,6,7	Kharif	Dry	50	37	40	25	37	40	25	0	0	2.6	0	1.05	0
38	bajra	1,2,3	Kharif	Irrigated	100	50	25	50	50	25	50	0	0	0	0	0	0
39	Bajra	1,2,3	Summer	Irrigated	100	50	25	50	50	25	50	0	0	0	0	0	0
40	Bajra	1	Kharif	Dry	50	25	0	50	25	0	0	0	0	0	0	0	0
41	Bajra	2,3,8,	Kharif	Dry	50	25	0	50	25	0	0	0	0	0	0	0	0
42	Bajra	4,5,6	Kharif	Irrigated	100	63	25	50	63	25	50	0	0	0	0	0	0
43	Bajra	4,5,6	Kharif	Dry	50	25	0	50	25	0	0	0	0	0	0	0	0
44	Wheat	2,3,8,	Rabi	Irrigated	100	75	50	50	75	50	50	0	0	0	0	0	0
45	Wheat	2,3,8,	Rabi	Dry	50	25	0	50	25	0	0	0	0	0	0	0	0

46	Wheat	4,5,6,7,	Rabi	Irrigated	100	75	50	50	75	50	50	0	0	0	0	0	0
47	Wheat dicoccum	2,3,8	Rabi	Irrigated	60	30	20	30	30	20	30	0	0	0	0	0	0
48	Foxtail millet	2,3,8,	Kharif	Dry	30	15	15	15	15	15	15	0	0	0	0	0	0
49	Foxtail millet	4,5,6	Kharif	Dry	40	40	0	40	40	0	0	0	0	0	0	0	0
50	Pros millet	2,3,8,	Kharif	Dry	10	10	0	10	10	0	0	0	0	0	0	0	0
51	Kodo millet	4,5,6,	Kharif	Dry	20	20	0	20	20	0	0	0	0	0	0	0	0
52	Barnyard millet	2,3,8,	Kharif	Dry	10	20	0	10	20	0	0	0	0	0	0	0	0
53	Little millet	2,3,8,	Kharif	Dry	30	15	0	15	15	0	15	0	0	0	0	0	0
54	Little millet	4,5,6,	Kharif	Dry	20	20	0	20	20	0	0	0	0	0	0	0	0
55	Amaranthus	2,3,8	Kharif	Dry	100	50	50	50	50	50	50	0	0	0	0	0	0
56	Tur	1,2,3,8,	Kharif	Dry	25	50	25	25	50	25	0	0	0	0	0	0	0
57	Tur	4,5,6,7,	Kharif	Dry	25	50	25	25	50	25	0	0	0	3.07	0	0	18
58	Bengal gram	1,2,3,8,	Rabi	Irrigated	25	50	0	25	50	0	0	0	0	0	0	0	0
59	Bengal gram	1,2,3,8,	Rabi	Dry	10	25	0	10	25	0	0	0	0	0	0	0	0
60	Bengal gram	4,5,6,7,	Rabi	Irrigated	25	50	25	25	50	25	0	0	0	0	0	0	0
61	Bengal gram	4,5,6,7,	Rabi	Dry	13	25	25	13	25	25	0	0	0	0	0	0	0
62	Green gram	1,2,8	Kharif	Dry	25	50	0	25	50	0	0	0	0	0	0	0	0
63	Green gram	3	Kharif	Dry	13	25	0	13	25	0	0	0	0	0	0	0	0
64	Green gram	4,5,6,7,8,9,10	Kharif	Dry	13	25	25	13	25	25	0	0	0	2.05	0	0	0
65	Green gram	4,5,6,7,8,9,10	Kharif	Irrigated	25	50	50	25	50	50	0	0	0	2.05	0	0	0
66	Green gram	4,5,6,7,8,9,10	Summer	Irrigated	25	50	50	25	50	50	0	0	0	2.05	0	0	0

67	Black gram	1,2,3,8	Kharif	Dry	25	50	0	25	50	0	0	0	0	0	0	0	0
68	Black gram	4,5,6,7,8,9,10	Kharif	Dry	13	25	25	13	25	25	0	0	0	2.05	0	0	0
69	Black gram	4,5,6,7,8,9,10	Kharif	Irrigated	25	50	25	25	50	25	0	0	0	2.05	0	0	0
70	Black gram	4,5,6,7,8,9,10	Summer	Irrigated	25	50	25	25	50	25	0	0	0	2.05	0	0	0
71	Cowpea	1,2,8	Kharif	Dry	13	25	13	13	25	13	0	0	0	0	0	0	0
72	Cowpea	3	Kharif	Dry	13	25	0	13	25	0	0	0	0	0	0	0	0
73	Cowpea	4,5,6,7,8,9,10	Kharif	Dry	25	50	25	25	50	25	0	0	0	0	0	0	0
74	Lablab	4,5,6,7,	Kharif	Dry	25	50	25	25	50	25	0	0	0	0	0	0	0
75	Lablab	4,5,6,7,	Rabi	Irrigated	25	50	25	25	50	25	0	0	0	0	0	0	0
76	Lablab	4,5,6,7	Summer	Irrigated	25	50	25	25	50	25	0	0	0	0	0	0	0
77	Horse gram	1,2,3,8	Kharif	Dry	10	30	0	10	30	0	0	0	0	0	0	0	0
78	Horse gram	4,5,6,7	Kharif	Dry	25	38	25	25	38	25	0	0	0	0	0	0	0

Note: Dry indicates rainfed cultivation

Table 5.3 (b) Crop wise fertilizer recommendation- **For Oil seeds and Commercial crops**

Sl No	Crop	ACZ	Season	Dry/Irr	Total N kg/Ha	Total P_2O_5 kg/Ha	Total K^2O kg/Ha	Basal N kg/Ha	Basal P_2O_5 kg/Ha	Basal K^2O kg/Ha	Top dress N kg/Ha	Top Dress P_2O_5 kg/Ha	Top Dress K^2O kg/Ha	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	Groundnut	1,2,3,8	kharif	irrigated	25	75	38	25	75	38	0	0	0	2.05	0	1.05	0
2	Groundnut	1,2,3,8,	kharif	dry	18	45	25	18	45	25	0	0	0	2.05	0	1.05	0
3	Groundnut	1,2,3,8	summer	irrigated	25	75	38	25	75	38	0	0	0	2.05	0	1.05	0
4	Groundnut	4,5,6,7	kharif	irrigated	25	75	38	25	75	38	0	0	0	2.05	0	1.05	0
5	Groundnut	4,5,6,7	summer	irrigated	25	75	38	25	75	38	0	0	0	2.05	0	1.05	0
6	Groundnut	4,5,6,7	kharif	dry	25	50	25	25	50	25	0	0	0	2.05	0	1.05	0
7	Safflower	1,2,3,8,	rabi	irrigated	75	75	40	75	75	40	0	0	0	0	0	0	30
8	Safflower	1,2,3,8	rabi	dry	40	40	13	40	40	13	0	0	0	0	0	0	30
9	Safflower	4,5,6,7	rabi	dry	40	40	13	40	40	13	0	0	0	0	0	0	30

10	Sunflower	1,2,3,8,	kharif/rabi/summer	irrigated	80	80	60	80	80	60	0	0	0	2.05	0	1.6	0
11	Sunflower	1,2,3,8	kharif	dry	35	50	35	35	50	35	0	0	0	2.05	0	1.6	0
12	Sunflower	4,5,6,7	kharif/rabi/summer	irrigated	90	90	63	45	90	63	45	0	0	2.05	0	1.6	0
13	Sunflower	4,5,6,7	kharif	dry	38	50	38	19	50	38	19	0	0	2.05	0	1.6	0
14	Soybean	1,2,3,8	kharif	dry	40	80	25	40	80	25	0	0	0	2.6	0	0	0
15	Soybean	4,5,6,7	kharif/rabi/summer	irrigated	30	80	38	30	80	38	0	0	0	2.6	0	0	0
16	Soybean	4,5,6,7	kharif	dry	25	50	25	25	50	25	0	0	0	2.6	0	0	0
17	Caster	1,2,3,8,	kharif	dry	40	40	20	20	40	20	20	0	0	0	0	0	0
18	Caster	1,2,3,8,	kharif	irrigated	75	80	25	38	80	25	37	0	0	0	0	0	0
19	Caster	4,5,6,7	kharif	dry	38	38	25	19	38	25	19	0	0	0	0	0	0
20	Nizer	1,2,3,8,	kharif	dry	20	40	20	10	40	20	10	0	0	0	0	0	0
21	Nizer	4,5,6,7	kharif	dry	20	40	20	10	40	20	10	0	0	0	0	0	0
22	Sesame	1,2,3,8	kharif	dry	20	40	20	20	40	20	0	0	0	1.02	0	0.1	0
23	Sesame	4,5,6,7	kharif	dry	38	25	25	38	25	25	0	0	0	1.02	0	0.1	0
24	Flax seed	1,2,3,8	kharif	dry	40	20	20	40	20	20	0	0	0	0	0	0	0
25	Sugarcane	1,2,3,8,	kharif/summer	irrigated	250	75	188	25	75	188	225	0	0	0	0	0	0
26	Sugarcane	4,5,6	kharif/summer	irrigated	250	100	125	25	100	125	225	0	0	0	0	0	0
27	Sugarcane	7	kharif/summer	irrigated	250	75	75	25	75	75	225	0	0	0	0	0	0
28	Sugarcane	10	kharif	irrigated	188	125	125	19	125	125	169	0	0	0	0	0	0
29	Sugarcane-ratoon	4,5,6	kharif/summer	irrigated	250	100	125	84	100	125	186	0	0	0	0	0	0
30	Sugarcane-ratoon	7	kharif/summer	irrigated	250	75	75	84	75	75	186	0	0	0	0	0	0
31	Sugarcane-ratoon	10	kharif/summer	irrigated	188	125	125	63	125	125	125	0	0	0	0	0	0

32	Tobacco-beedi	3,8,	kharif	dry	125	50	40	62	50	40	63	0	0	0	0	0	0
33	Tobacco-verginia	7	kharif	dry	40	30	80	20	30	80	20	0	0	0	0	0	0
34	Cotton variety	2,3	kharif	dry	30	15	15	30	15	15	0	0	0	0	0	0	0
35	Cotton variety	8	kharif	dry	40	25	25	20	25	25	20	0	0	0	0	0	0
36	cotton hybrid	9	kharif	dry	100	100	100	50	100	100	50	0	0	0	0	0	0
37	Cotton hybrid	8	kharif	dry	80	20	20	40	20	20	40	0	0	0	0	0	0
38	Cotton bt	1,2,3,8,	kharif	dry	100	50	50	50	50	50	50	0	0	0	0	0	0
39	Cotton bt intraspecies	1,2,3,8	kharif	dry	94	60	60	31	62	16	63	0	44	0	0	0	0
40	Cotton hybrid intraspecies	1,2,3,8,	kharif	irrigated	150	75	75	75	75	75	75	0	0	0	0	0	0
41	Cotton hybrid inter species	1,2,3,8	kharif	irrigated	120	60	60	60	60	60	60	0	0	0	0	0	0
42	Cotton bt interspecies	8	kharif	irrigated	200	30	30	50	10	10	150	20	20	0	0	0	0
43	Cotton bt intraspecies	3	kharif	irrigated	150	90	60	30	90	15	120	0	45	0	0	0	0
44	Cotton variety	1,2,3,8,	summer	irrigated	80	20	20	40	20	20	40	0	0	0	0	0	0
45	Cotton hybrid	1,2,3,8	summer	irrigated	120	60	60	60	60	60	60	0	0	0	0	0	0
46	Cotton all variety	4,5,6,7	kharif	irrigated	150	75	75	75	75	75	75	0	0	0	0	9	0

Dry indicates rainfed cultivation

Table 5.3 (c) Crop wise fertilizer recommendation- **For Vegetables**

S. No	Crop	ACZ	Season	Dry/Irr	Total N kg/Ha	Total P_2O_5 kg/Ha	Total K^2O kg/Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	Tomato hybrid	1,2,3,4,5,6,7,8,9,10	kharif/rabi/summer	irrigated	250	250	250	125	250	250	125	0	0	0	0		0
2	Tomato variety	1,2,3,4,5,6,7,8,9,10	kharif/rabi/summer	irrigated	115	100	60	58	100	60	57	0	0	0	0	0	0
3	Tomato	1,2,3,4,5,6,7,8,9,10	kharif	dry	60	50	30	30	50	30	30	0	0	0	0	0	0
4	Potato	1,2,3,4,5,6,7,8,9,10	kharif/rabi/summer	irrigated	125	100	125	62	100	125	63	0	0	0	0	0	0
5	Potato	1,2,3,4,5,6,7,8,9,10	kharif	dry	75	75	100	37	75	75	38	0	0	0	0	0	0
6	Brinjal	10	kharif/rabi/summer	irrigated	150	50	75	75	50	75	75	0	0	0	0	0	0
7	Brinjal	1,2,3,4,5,6,7,8,9	kharif/rabi/summer	irrigated	125	100	50	62	100	50	63	0	0	0	0	0	0
8	Chillies	1,2,3,4,5,6,7,8,9,10	kharif/rabi/summer	irrigated	150	75	75	75	75	75	75	0	0	0	0	0	0
9	Chillies	1,2,3,4,5,6,7,8,9 10	kharif	dry	100	50	50	50	50	50	50	0	0	0	0	0	0
10	Capsicum	1 to 10	kharif/rabi/summer	irrigated	150	75	50	75	75	50	75	0	0	0	0	0	0
11	Cabbage	1 to 10	kharif/rabi	irrigated	150	100	125	75	100	125	75	0	0	0	0	0	0
12	Cauliflower	1 to 10	kharif/rabi	irrigated	150	100	125	75	100	125	75	0	0	0	0	0	0
13	Knolkhol	1 to 10	kharif/rabi	irrigate	150	100	125	75	100	125	75	0	0	0	0	0	0

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14	Bhendi	1 to 10	kharif/summer	irrigated	125	75	63	62	75	63	63	0	0	0	0	0	0
15	Beans	1 to 10	kharif/rabi/summer	irrigated	63	100	75	31	100	75	32	0	0	0	0	0	0
16	Peas	1 to 10	kharif/rabi	irrigated	38	60	50	38	60	50	0	0	0	0	0	0	0
17	Cowpea	1,2,3,4,5,6,7,8,89	kharif/summer	irrigated	25	75	60	25	75	60	0	0	0	0	0	0	0
18	Cowpea	10	kharif/summer	irrigated	25	75	60	12	75	60	13	0	0	0	0	0	0
19	Lablab	1 to 10	kharif/summer	irrigated	25	50	75	25	50	75	0	0	0	0	0	0	0
20	Clusterbean	1 to 10	kharif/summer	irrigated	25	75	60	25	75	60	0	0	0	0	0	0	0
21	Watermelon	1 to 10	rabi	irrigated	100	88	100	50	88	100	50	0	0	0	0	0	0
22	Cucumber	1 to 10	kharif/summer	irrigated	60	50	80	30	50	80	30	0	0	0	0	0	0
23	Gerkin	1 to 10	summer	irrigated	260	175	260	130	175	260	130	0	0	0	0	0	0
24	Pumpkin	1 to 10	kharif/summer	irrigated	100	40	100	50	40	100	50	0	0	0	0	0	0
25	Pumpkin sqash	1 to 10	kharif/summer	irrigated	88	50	40	44	50	40	44	0	0	0	0	0	0
26	Ashgourd	1 to 10	kharif/rabi/summer	irrigated	50	50	50	25	50	50	25	0	0	0	0	0	0
27	Bottlegourd	1 to 10	kharif/rabi/summer	irrigated	50	38	25	50	38	25	0	0	0	0	0	0	0
28	Bittergourd	1 to 10	kharif/summer	irrigated	63	50	50	31	50	50	32	0	0	0	0	0	0

29	Ridgegourd	1 to 10	kharif/summer	irrigated	50	50	50	25	50	50	25	0	0	0	0	0	0
30	Chowchow	1 to 10	kharif/summer	irrigated	43	43	43	8	8	8	35	35	35	0	0	0	0
31	Coccinia	1 to 9	kharif	irrigated	50	100	50	17	33	17	33	67	33	0	0	0	0
32	Coccinia	10	rabi	irrigated	100	75	100	33	25	33	67	50	67	0	0	0	0
33	Beetroot	1 to 10	kharif /summer	irrigated	75	100	60	37	100	60	38	0	0	0	0	0	0
34	Carrot	1 to 10	kharif/rabi/summer	irrigated	50	50	50	50	50	50	0	0	0	0	0	0	0
35	Raddish	1 to 10	kharif/rabi/summer	irrigated	50	100	50	50	100	50	0	0	0	0	0	0	0
36	Turnip	1 to 10	kharif/rabi/summer	irrigated	75	40	40	37	40	40	38	0	0	0	0	0	0
37	Onion	1 t 10	kharif/rabi/summer	irrigated	125	75	125	62	75	125	63	0	0	0	0	0	0
38	Sweetpotato	1 to 9	kharif/rabi	irrigated	75	50	75	37	50	75	38	0	0	0	0	0	0
39	Sweetpotato	10	rabi	irrigated	75	50	75	37	50	37	38	0	38	0	0	0	0
40	Topioca	1 to 9	kharif	irrigated	75	75	100	37	37	50	38	38	50	0	0	0	0
41	Topioca	10	kharif	irrigated	120	60	180	60	30	90	60	30	90	0	0	0	0
42	Amarphopalus	1 to 9	kharif	irrigated	80	60	100	40	60	100	40	0	0	0	0	0	0
43	Amarphopalus	10	kharif	irrigated	80	60	100	40	60	50	40	0	0	0	0	0	0
44	Amaranthus	1 to 10	kharif/summer	irrigated	100	50	50	50	50	50	50	0	0	0	0	0	0

45	Methi	1 to 10	rabi	irrigated	100	50	0	50	50	0	50	0	0	0	0	0	0
46	Palak	1 to 10	rabi	irrigated	150	100	100	150	100	100	0	0	0	0	0	0	0
47	Lettuce	1 to 10	kharif/summer	irrigated	150	100	100	75	100	100	75	0	0	0	0	0	0
48	Coriander	1 to 10	kharif/summer	irrigated	35	35	35	17	35	35	18	0	0	0	0	0	0
49	Drumstick	1 to 10	kharif/rabi/summer	irrigated	50	125	30	25	62	15	25	63	15	0	0	0	0
50	Dell	1 to 10	kharif/rabi/summer	irrigated	25	0	0	25	0	0	0	0	0	0	0	0	0
51	Curry leaf	1 to 10	1 year	irrigated	50	25	25	12	6	6	38	19	19	0	0	0	0
	1 to 10	2 year	irrigated	150	37	37	37	9	9	113	28	28	0	0	0	0	
	1 to 10	3 year	irrigated	300	50	50	75	12	12	225	38	38	0	0	0	0	

Dry indicates rainfed cultivation

Table 5.3 (d) Crop wise fertilizer recommendation- **For Fruit Crops**

S. NO	Crop	ACZ	Season	Dry/Irr	Total N kg/ Ha	Total P_2O_5 kg/ Ha	Total K^2O kg/Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ ha	Fe kg/ ha	B kg/ ha	S kg/ ha
1	Mango	1,2,3,4,5.6.7.8	1 year	dry/irrigated	7.5	2	7	7.5	2	7	0	0	0	0	0	0	0
			2 year	dry/irrigated	14.6	3.6	13.6	14.6	3.6	14.6	0	0	0	0	0	0	0
			3 year	dry/irrigated	21.9	5.4	20.4	21.9	5.4	20.4	0	0	0	0	0	0	0
			4 year	dry/irrigated	29.2	7.2	27.2	29.2	7.2	27.2	0	0	0	0	0	0	0
			5 year	dry/irrigated	36.5	9	34	36.5	9	34	0	0	0	0	0	0	0
			6 year	dry/irrigated	43.8	10.8	40.8	43.8	10.8	40.8	0	0	0	0	0	0	0
			7 year	dry/irrigated	51.1	12.6	47.6	51.1	12.6	47.6	0	0	0	0	0	0	0
			8 year	dry/irrigated	58.4	14.4	54.4	58.4	14.4	54.4	0	0	0	0	0	0	0
			9 year	dry/irrigated	65.7	16.2	61.2	65.7	16.2	65.7	0	0	0	0	0	0	0
			10 year &after	dry/irrigated	73	18	68	73	18	68	0	0	0	0	0	0	0
	Mango	9	1 year	dry/irrigated	15	4	14	15	4	14	0	0	0	0	0	0	0
			2 year	dry/irrigated	14.5	3.5	13.5	14.5	3.5	13.5	0	0	0	0	0	0	0
			3 year	dry/irrigated	14.5	3.5	13.5	14.5	3.5	13.5	0	0	0	0	0	0	0

			4 year	dry/irrigated	36.5	9	34	36.5	9	34	0	0	0	0	0	0	0
			5 year	dry/irrigated	36.6	9	34	36.5	9	34	0	0	0	0	0	0	0
			6 year	dry/irrigated	36.5	9	34	36.5	9	34	0	0	0	0	0	0	0
			7 year	dry/irrigated	58	15	55	58	15	55	0	0	0	0	0	0	0
			8 year	dry/irrigated	58	15	55	58	15	55	0	0	0	0	0	0	0
			9 year	dry/irrigated	58	15	55	58	15	55	0	0	0	0	0	0	0
			10 year &after	dry/irrigated	73	18	70	73	18	70	0	0	0	0	0	0	0
	Mango	10	1 year	dry/irrigated	3.8	1	3.5	3.8	1	3.5	0	0	0	0	0	0	0
			2 year	dry/irrigated	14.6	3.6	13.6	14.6	3.6	13.6	0	0	0	0	0	0	0
			3 year	dry/irrigated	21.9	5.4	20.4	21.9	5.4	20.4	0	0	0	0	0	0	0
			4 year	dry/irrigated	29.2	7.2	27.2	29.2	7.2	27.2	0	0	0	0	0	0	0
			5 year	dry/irrigated	36.5	9	34	36.5	9	34	0	0	0	0	0	0	0
			6 year	dry/irrigated	43.8	10.8	40.8	43.8	10.8	40.8	0	0	0	0	0	0	0
			7 year	dry/irrigated	51.1	12.6	47.6	51.1	12.6	51.1	0	0	0	0	0	0	0
			8 year	dry/irrigated	58.4	14.4	54.4	58.4	14.4	54.4	0	0	0	0	0	0	0
			9 year	dry/irrigated	65.7	16.2	61.2	65.7	16.2	65.7	0	0	0	0	0	0	0

			10 year 7after	dry/irrigated	73	18	68	73	18	68	0	0	0	0	0	0	0
2	Banana-pachabale/robusta	1,2,3,4,5,6,7,8,9,10	kharif/summer	irrigated	540	325	675	180	108	225	360	145	450	0	0	0	0
	Banana other varieties	1,2,3,4,5,6,7,8,9,10	kharif/summer	irrigated	400	240	500	133	80	166	267	160	334		0	0	0
	Banana tissue culture	1,2,3,4,5,6,7,8,9,10	kharif/summer	irrigated	616	308	925	62	62	111	554	246	814	0	0	0	0
3	Lime	1,2,3,4,5,6,7,8,9,10	1 year	irrigated	27.7	16.6	27.7	9.2	5.5	9.2	18.5	11.1	18.5	0	0	0	0
			2 year	irrigated	55.4	33.2	55.4	18.5	11.1	18.5	38.9	22.1	38.9	0	0	0	0
			3 year	irrigated	83.1	49.8	83.1	27.7	16.6	27.7	55.4	33.2	55.4	0	0	0	0
			4 year	irrigated	110.8	66.5	110.8	36.9	22.2	36.9	73.9	44.3	73.9	0	0	0	0
			5 year &after	irrigated	138.5	83.1	138.5	46.2	27.7	46.2	92.3	45.4	92.3	0	0	0	0
4	Orange	1,2,3,4,5,6,7,8,9,10	1 year	irrigated	10	10	3.5	3.3	3.3	1.2	6.7	6.7	2.3	0	0	0	0
			2 year	irrigtated	33	22	33	11	7	11	22	15	22	0	0	0	0
			3 year	irrigated	75	50	75	25	17	25	50	33	50	0	0	0	0
			4 year	irrigated	111	50	75	37	17	25	74	33	50	0	0	0	0
			5 year& after	irrigated	152	102	152	51	34	51	101	68	101	0	0	0	0
5	Grapes Anabi shahi	1,2,3,4,5,6,7,8	2 to 5 years	irrigated	500	250	750	150	125	0	350	125	750	0	0	0	0
			6 year & after	irrigated	1000	500	1000	300	250	0	700	250	1000	0	0	0	0
	Grapes-Thomson seedless	1,2,3,4,5,6,7,8	2 year &after	irrigated	300	500	1000	180	250	0	120	250	1000	0	0	0	0
6	Guava	1,2,3,4,5,6,7,8,	1 to 3 years	irrigated	14	7	21	14	7	21	0	0	0	0	0	0	0

		9,10															
			4 to 6 years	irrigated	28	11	21	28	11	21	0	0	0	0	0	0	0
			7 to 10 years	irrigaetd	55	22	42	55	22	42	0	0	0	0	0	0	0
			11-year 7after	irrigated	83	33	42	83	33	42	0	0	0	0	0	0	0
7	Chicku	1,2,3,4,5,6,7,8, 9,10	1 to 3 years	irrigated	5	2	7.5	1.7	0.7	2.5	3.3	1.3	5	0	0	0	0
			4 to 6 years	irrigated	10	4	15	3.3	1.3	5	6.7	2.7	10	0	0	0	0
			7 to 10 years	irrigated	15	6	22.5	5	2	7.5	10	4	15	0	0	0	0
			11 years 7after	irrigated	40	16	45	13.3	5.3	15	26.7	10.7	30	0	0	0	0
8	Papaya solo variety	1,2,3,4,5,6,7,8, 9,10	kharif/summer	irrigated	772	772	154	129	129	26	643	643	128	0	0	0	0
	Papaya other varieties	1,2,3,4,5,6,7,8, 9,10	kharif/summer	irrigated	434	434	868	72	72	145	362	362	723	0	0	0	0
9	Pomagranate	1,2,3,4,5,6,7,8	kharif	irrigated	197	99	99	197	99	99	0	0	0	0	0	0	0
10	Pineapple	,4,5,6,7,8,,10	kharif	irrigated	525	130	175	131	130	44	394	0	131	0	0	0	0
		9	kharif	irrigated	350	130	440	88	130	110	262	0	330	0	0	0	0
11	Custard apple	1,2,3,4,5,6,7,8	1 to 2 years	irrigated	37	25	25	37	25	25	0	0	0	0	0	0	0
			3 to 5 years	irrigated	74	49	49	74	49	49	0	0	0	0	0	0	0
			5 years &after	irrigated	123	62	62	123	62	62	0	0	0	0	0	0	0
12	Amla	1,2,3,4,5,6,7,8	1 to 2 years	irrigated	7.5	5	5	7.5	5	5	0	0	0	0	0	0	0
			3 to 5 years	irrigated	15	10	10	15	10	10	0	0	0	0	0	0	0
			after 5 years	irrigated	30	20	20	30	20	20	0	0	0	0	0	0	0
	Phyllanthus acidus	1,2,3,4,5,6,7,8	1 to 2 years	irrigated	30	20	20	30	20	20	0	0	0	0	0	0	0

			3 to 5 years	irrigated	60	40	40	60	40	40	0	0	0	0	0	0	0
			after 5 years	irrigated	120	80	80	120	80	80	0	0	0	0	0	0	0
13	Fig	1,2,3,4,5,6,7,8	1 to 2 years	irrigated	50	33	33	50	33	33	0	0	0	0	0	0	0
			3 to 5 years	irrigated	100	66	66	100	66	66	0	0	0	0	0	0	0
			after 5 years	irrigated	200	132	132	200	132	132	0	0	0	0	0	0	0
14	Jack	1,2,3,4,5,6,7,8, 9,10	1 to 3 years	dry/irrigated	20	12	6	10	6	3	10	6	3	0	0	0	0
			4 to 7 years	dry/irrigated	40	24	12	20	12	6	20	12	6	0	0	0	0
			after 7 years	dry/irrigated	60	30	18	30	15	9	30	15	9	0	0	0	0
15	Ber	1,2,3,4,5,6,7,8,	1 to 2 years	dry/irrigated	20	14	14	20	14	14	0	0	0	0	0	0	0
			3 to 5 years	dry/irrigated	40	28	28	40	28	28	0	0	0	0	0	0	0
			after 5 years	dry/irrigated	140	56	56	140	56	56	0	0	0	0	0	0	0
16	Jamoon	1,2,3,4,5,6,7,8	1 year onwards	dry/irrigated	50	20	20	50	20	20	0	0	0	0	0	0	0
17	Fashon fruit	1,2,3,4,5,6,7,8	1 year onwards	dry/irrigated	167	84	167	167	84	167	0	0	0	0	0	0	0
18	Butter fruit	1,2,3,4,5,6,7,8	1 to 3 years	irrigated	14	5.75	14	14	5.75	14	0	0	0	0	0	0	0
			4 to 6 years	irrigated	28	8	28	28	8	28	0	0	0	0	0	0	0
			7 to 10 years	irrigated	42	14	42	42	14	42	0	0	0	0	0	0	0
			after 10 years	irrigated	56	20	56	56	20	56	0	0	0	0	0	0	0

Dry indicates rainfed cultivation

Table 5.3 (e) Crop wise fertilizer recommendation- **For Plantation Crops**

S. NO	Crop	ACZ	Season	Dry/Irr	Total N kg/Ha	Total P_2O_5 kg/Ha	Total K^2O kg/Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	Coconut tall variety	1,2,3,4,5,6,7,8,9,	1 year	dry/irrigated	6.14	4.9	16.6	6.14	4.9	16.6	0	0	0	0	0	0	0
			2 year	dry/irrigated	19.64	14.7	49.8	6.14	4.9	16.6	13.5	9.8	33.2	0	0	0	0
			3 year	dry/irrigated	40.5	29.4	99.6	13.5	9.8	33.2	27	19.6	66.4	0	0	0	0
			4 year &after	dry/irrigated	61.5	39.3	147.6	20.9	14.7	49.2	40.6	24.6	98.4	0	0	0	0
2	Coconut tall 10		1 year	dry/irrigated	8.9	7.1	24.3	0	0	0	8.9	7.1	24.3	0	0	0	0
			2 year	dry/irrigated	28.4	21.3	72.3	8.9	7.1	24.3	19.5	14.2	48	0	0	0	0
			3 year	dry/irrigated	58.7	42.7	144.1	19.5	14.2	48	39.2	28.5	96.1	0	0	0	0
			4 year &after	dry/irrigated	88.9	56.9	213.2	30.2	21.3	71.2	58.7	35.6	142	0	0	0	0
3	Coconut dwarf	1,2,3,4,5,6,7,8,9, 10	1 year	dry/irrigated	8.9	7.1	24.3	0	0	0	8.9	7.1	24.3	0	0	0	0
			2 year	dry/irrigated	28.4	21.3	72.3	8.9	7.1	24.3	19.5	14.2	48	0	0	0	0
			3 year	dry/irrigated	58.7	42.7	144.1	19.5	14.2	48	39.2	28.5	96.1	0	0	0	0
			4 year &after	dry/irrigated	88.9	56.9	213.2	30.2	21.3	71.2	58.7	35.6	142	0	0	0	0
4	Arecanut	1,2,3,4,5,6,7,8,9,	1 year	irrigated	46	18	64	23	9	32	23	9	32	0	0	0	0

	local	10														
			2 year	irrigated	91	36	128	45	18	64	46	18	64	0	0	0	0
			3 year &after	irrigated	137	55	192	68	28	96	69	27	69	0	0	0	0
5	Arecanut improved variety	1,2,3,4,5,6,7,8,9, 10	1 year	irrigated	68	27	96	34	14	48	34	13	48	0	0	0	0
			2 year	irrigated	137	55	191	69	28	95	68	27	96	0	0	0	0
			3 year &after	irrigated	205	82	288	103	41	144	102	41	144	0	0	0	0
6	Palm	789 10	1 year	irrigated	58	29	58	29	14.5	29	29	14.5	29	0	0	0	0
			2 year	irrigated	114	57	114	57	28	57	57	29	57	0	0	0	0
			3 year &after	irrigated	172	86	172	86	43	86	86	43	86	0	0	0	0
7	Rubber	9,10	1 year	irrigated	10	10	4	5	5	2	5	5	2	0	0	0	0
			2 year	irrigated	36	36	16	18	18	8	18	18	8	0	0	0	0
			3 year	irrigated	44	44	20	22	22	10	22	22	10	0	0	0	0
			4 year	irrigated	36	36	16	18	18	8	18	18	8	0	0	0	0
			5 year &onwards	irrigated	56	36	24	28	18	14	28	18	14	0	0	0	0
8	Cashew	1,2,3,4,5,6,7,8,9,	1 year	irrigated	9	9	9	4.5	4.5	4.5	4.5	4.5	4.5	0	0	0	0
			2 year	irrigated	20	20	20	10	10	10	10	10	10	0	0	0	0
			3 year	irrigated	39	19.5	19.5	19.5	10	10	19.5	9.5	9.5	0	0	0	0
			4 year	irrigated	78	19.5	19.5	39	10	10	39	9.5	9.5	0	0	0	0
			5 year 7onwards	irrigated	78	39	39	39	20	20	39	19	19	0	0	0	0
9	Coffee	7,8,9	1 year	irrigated	24	15	24	6	3.5	6	18	11.5	18	0	0	0	0
			2 to 3	irrigated	30	24	30	7.5	6	7.5	22.5	18	22.5	0	0	0	0

			years													
			4 year	irrigated	39	30	39	10	7.5	10	29	22.5	29	0	0	0	0
			5 year &onwards	irrigated	72	45	72	18	11	18	54	34	54	0	0	0	0
10	Cocoa	4,5,6,7,8,9	1 year	irrigated	30	10	40	30	10	40	0	0	0	0	0	0	0
			2 year	irrigated	55	22	76	55	22	76	0	0	0	0	0	0	0
			3 year	irrigated	82	33	115	82	33	115	0	0	0	0	0	0	0
			4 year &onwards	irrigated	110	44	153	110	44	153	0	0	0	0	0	0	0
11	Beetle vine	1,2,3,4,5,6,7,8,9	1 year on wards	irrigated	750	750	750	750	750	750	0	0	0	0	0	0	0
12	Tamrind	1,2,3,4,5,6,7,8,	1 to 10 years	dry/irrigated	4	1.8	4	4	1.8	4	0	0	0	0	0	0	0
			after 10 years	dry/irrigated	40	20	40	40	20	40	0	0	0	0	0	0	0
13	Black pepper	7,8,9	1 year	irrigated	36	15	51	18	7.5	25.5	18	7.5	25.5	0	0	0	0
			2 year	irrigated	73	30	102	36	15	51	36	15	51	0	0	0	0
			3 year &after	irrigated	110	44	154	55	22	77	55	22	77	0	0	0	0
14	Cardomum	7,8,9	1 year	irrigated	40	40	80	0	0	0	40	40	80	0	0	0	0
			2 year	irrigated	40	40	80	20	20	40	20	20	40	0	0	0	0
			3 year &after	irrigated	75	75	150	37.5	37.5	75	37.5	37.5	75	0	0	0	0
15	Turmeric	1,2,3,4,5,6,7,8,9 10	kharif	irrigated	150	125	250	75	125	250	75	0	0	0	0	0	0
16	Ginger	1,2,3,4,5,6,7,8,9	kharif	irrigated	100	50	50	0	50	50	100	0	0	0	0	0	0

		10														
17	Garlic	1,2,3,4,5,6,7,8	kharif/ rabi	irrigated	125	62.5	62.5	62.5	62.5	62.5	62.5	0	0	0	0	0	0
18	Cinomon	7,8,9	1 year to 10 years	irrigated	22	19	27	11	9.5	13.5	11	9.5	13.5	0	0	0	0
			after 10 years	irrigated	216	194	243	108	97	122	108	97	123	0	0	0	0
19	Clove	7,8,9	1 to 10 years	irrigated	5.6	5	14	2.8	2.5	7	2.8	2.5	7	0	0	0	0
			11 to 15 years	irrigated	56	50	140	28	25	70	28	25	70	0	0	0	0
			after 15 years	irrigated	84	70	210	42	35	105	42	35	105	0	0	0	0
20	Nutmug	7,8,9	1 to 10 years	irrigated	8	7	20	4	3.5	10	4	3.5	10	0	0	0	0
			11 to 15 years	irrigated	80	72	200	40	36	100	40	36	100	0	0	0	0
			15 year after	irrigated	200	100	400	100	50	200	100	50	200	0	0	0	0
21	Aii spice	7,8,9	1 to 10 years	irrigated	6	5	14	3	2.5	7	3	2.5	7	0	0	0	0
			11 to 15 years	irrigated	56	50	139	28	25	70	28	25	69	0	0	0	0
22	Venilla	7,8,9	1 to 5 years	irrigated	80	40	120	80	40	120	0	0	0	0	0	0	0
			after 5 years	irrigated	120	60	200	120	60	200	0	0	0	0	0	0	0
23	Cocum	7,8,9	1 year	irrigated	16	7	20	16	7	20	0	0	0	0	0	0	0
			2 to 4 years	irrigated	16	14	40	16	14	40	0	0	0	0	0	0	0
			5 to 10	irrigated	40	36	100	40	36	100	0	0	0	0	0	0	0

			years													
			10 to 15 years	irrigated	160	80	200	160	80	200	0	0	0	0	0	0	0
			after 15 years	irrigated	200	100	400	200	100	400	0	0	0	0	0	0	0

Table 5.3 (f) Crop wise fertilizer recommendation- **For Flower Crops**

S. NO	Crop	ACZ	Season	Dry/Irr	Total N kg/ Ha	Total P_2O_5 kg/Ha	Total K^2O kg/ Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	Jasmine jasminum multiflorum	1,2,3,4,5,6,7,8, 9,10,	1 to 2 years	irrigated	208	416	416	35	70	70	173	346	346	0	0	0	0
			3 to 5 years	irrigated	416	833	833	70	138	138	346	695	695	0	0	0	0
			after 5 years	irrigated	833	1666	1666	138	277	277	695	1389	1389	0	0	0	0
2	Jasminum ariculatum and jasminum samback	1,2,3,4,5,6,7,8, 9,10	1 to 2 years	irrigated	133	266	266	22	44	44	111	222	222		0	0	0
			3 to 5 years	irrigated	266	533	533	44	88	88	222	445	445	0	0	0	0
			after 5 years	irrigated	533	1066	1066	88	176	176	445	890	890	0	0	0	0
3	Jasminum grandi	1,2,3,4,5,6,7,8, 9,10,	1to 2years	irrigated	100	200	200	17	34	34	83	166	166	0	0	0	0

	florum																
			3 to 5 years	irrigated	200	400	400	34	68	68	166	332	332	0	0	0	0
			after 5 years	irrigated	400	800	800	67	133	133	333	667	667	0	0	0	0
4	Crosandra	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	100	60	60	40	60	60	60	0	0	0	0	0	0
5	Rose 60 cmX60 cm	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	278	278	417	139	139	209	139	139	208	0	0	0	0
	Rose - 75 cmX75 cm	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	179	179	268	90	90	134	89	89	134	0	0	0	0
	Rose 90cm X 90cm	1,2,3,4,5,6,7,8, 9,19,	kharif	irrigated	123	123	185	62	62	143	61	61	142	0	0	0	0
6	Crysantham um	1,2,3,4,5,6,7,8, 9,10	kharif	irrigated	99	150	100	33	150	100	66	0	0	0	0	0	0
7	Marygold	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	225	60	60	125	60	60	100	0	0	0	0	0	0
8	China aster	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	180	120	60	90	120	60	90	0	0	0	0	0	0
9	Tube rose single variety	1,2,3,4,5,6,7,8, 9,10,	kharif	irrigated	100	50	50	50	50	50	50	0	0	0	0	0	0
10	Tube rose double variety	1,2,3,4,5,6,7,8, 9,10	kharif	irrigated	200	150	150	100	150	150	100	0	0	0	0	0	0
11	Gladiolus	1,2,3,4,5,6,7,8, 9,10,	kharif rabi	irrigated	100	60	60	50	60	60	50	0	0	0	0	0	0
12	Glylardia	1,2,3,4,5,6,7,8, 9,10	kharif/rabi/summer	irrigated	150	80	60	75	80	60	75	0	0	0	0	0	0
13	Jerbera poly house	1,2,3,4,5,6,7,8, 9.10,	kharif/rabi/summer	irrigated													

14	Carnation poly house	1,2,3,4,5,6,7,8, 9,10		irrigated										0	0	0	0
15	Anthurium poly house																
16	Daijee	1,2,3,4,5,6,7,8, 9,10	kharif	irrigated	150	100	60	75	100	60	75	0	0	0	0	0	0
17	Spatica	1,2,3,4,5,6,7,8, 9,10	kharif	irrigated	100	60	80	50	60	80	50	0	0	0	0	0	0
18	Golden rod	1,2,3,4,5,6,7,8, 9,10	kharif	irrigated	100	50	50	50	50	50	50	0	0	0	0	0	0

Table 5.3 (g) Crop wise fertilizer recommendations- **For Medicinal and Aromatic Crops**

S. No	Crop	ACZ	Season	Dry/Irr	Total N kg/ Ha	Total P_2O_5 kg/ Ha	Total K^2O kg/ Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	Ashwagandha(withania somnifera)	1,2,3,4,5,6,7,8, 9,10	kharif	dry/irrigated	0	20	60	0	20	60	0	0	0	0	0	0	0
2	Kashikanagale(priwinkle-vinca rosea)	1,2,3,4,5,6,7,8, 9,10,	kharif	dry/irrigated	40	30	30	40	30	30	0	0	0	0	0	0	0
3	Makandi(cholius forkholii)	1,2,3,4,5,6,7,8, 9,10	kharif	dry	40	60	50	40	60	50	0	0	0	0	0	0	0
				irrigated	50	50	50	50	50	50	0	0	0	0	0	0	0
4	Relabevu(andrographtus paniculata)	1,2,3,4,5,6,7,8, 9,10	kharif	dry/irrigated	75	75	50	38	75	50	37	0	0	0	0	0	0
5	Aloevera	1,2,3,4,5,6,7,8	kharif	dry/irrigated	50	50	50	50	50	50	0	0	0	0	0	0	0
6	Sarpagandha(rauwolfia serpentina)	1,2,3,4,5,6,7,8, 9,10	kharif	dry/irrigated	60	30	30	20	30	30	40	0	0	0	0	0	0

7	Safedmusli(chlorophytum borrivillanium)	1,2,3,4,5,6,7,8,910	kharif	dry/irrigated	62	100	100	62	100	100	0	0	0	0	0	0	0
8	Hippali(piper longum)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	50	20	75	25	20	75	25	0	0	0	0	0	0
9	Stevia	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	60	30	45	30	30	45	30	0	0	0	0	0	0
10	Baje(achorus celemus)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	25	50	60	9	50	60	16	0	0	0	0	0	0
11	Madhunashini(oscimum tenniflorum)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	90	45	35	45	45	30	45	0	0	0	0	0	0
12	Tulsi(holy basil)	1,2,3,4,5,6,7,8,910	kharif	dry/irrigated	125	75	60	63	75	60	62	0	0	0	0	0	0
13	Rosemary	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	100	40	40	20	40	40	80	0	0	0	0	0	0
14	Panneer(withania wagalense)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	210	35	35	35	35	35	175	0	0	0	0	0	0
15	Dhavana(artimisia pallens)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	120	40	40	0	40	40	120	0	0	0	0	0	0
16	Lemongrass	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	250	100	60	40	100	60	210	0	0	0	0	0	0
17	Citronell grass	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	250	80	40	0	80	40	250	0	0	0	0	0	0
18	Palmrosegrass	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	60	50	40	20	50	40	40	0	0	0	0	0	0
19	Pacholi(pogostemon cablin)	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	150	50	50	25	50	50	125	0	0	0	0	0	0
20	Khus grass	1,2,3,4,5,6,7,8,9,10	kharif	dry/irrigated	25	25	25	25	25	25	0	0	0	0	0	0	0

Table 5.3 (h) Crop wise fertilizer recommendations- **For Fodder Crops**

S. No	Crop	ACZ	Season	Dry/Irr	Total N kg/Ha	Total P_2O_5 kg/Ha	Total K^2O kg/Ha	Basal N	Basal P_2O_5	Basal K^2O	Top Dress N	Top Dress P_2O_5	Top Dress K^2O	Zn kg/ha	Fe kg/ha	B kg/ha	S kg/ha
1	NB -21 grass	1,2,3,4,5,6,7,8,9	kharif	dry	150	90	60	15	90	60	135	0	0	0	0	0	0
			kharif	irrigated	180	120	80	18	120	80	162	0	0	0	0	0	0
2	Paragrass	1,2,3,4,5,6,7,	kharif	dry/irrigated	120	60	40	20	60	40	100	0	0	0	0	0	0
3	Fodder jowar	1,2,3,4,5,6,7	kharif	dry	40	20	15	20	20	15	20	0	0	0	0	0	0
			kharif	irrigated	100	50	50	75	50	50	75	0	0	0	0	0	0
4	Fodder maize	1,2,3,4,5,6,7,8	kharif	dry	100	25	13	50	25	75	50	0	0	0	0	0	0
				irrigated	150	100	50	75	100	50	75	0	0	0	0	0	0
5	BH-18 grass	1,2,3,4,5,6,7,8,9, 10	kharif	dry	150	100	60	25	100	60	125	0	0	0	0	0	0
				irrigated	180	120	80	30	120	80	150	0	0	0	0	0	0
6	Guinea grass	1,2,3,4,5,6,7,8,9, 10	kharif	irrigated	200	50	25	25	50	25	175	0	0	0	0	0	0
7	Green panic	1,2,3,4,5,6,7,8,9, 10	kharif	dry/irrigated	150	25	25	15	25	25	135	0	0	0	0	0	0
8	Rhodes grass	1.2,3,4,5,6,7,8,9 10	kharif	dry/irrigated	150	100	50	15	10	5	135	90	45	0	0	0	0
9	Congo & signal grass	1,2,3,4,5,6,7,8,9 10,	kharif	dry/irrigated	250	150	100	60	150	100	190	0	0	0	0	0	0

Table 5.4. Soil fertility criteria for adjusting the recommended fertilizer doses for macro nutrient application (NPK).

Nutrient	Very Low	Low	Medium	High	Very High
Nitrogen	Recommended dose x 1.67	Recommended dose x 1.33	Recommended dose x 1.00	Recommended dose x 0.67	Recommended dose x 0.33
P2O5	Recommended dose x 1.67	Recommended dose x 1.33	Recommended dose x 1.00	Recommended dose x 0.67	Recommended dose x 0.33
K2O	Recommended dose x 1.67	Recommended dose x 1.33	Recommended dose x 1.00	Recommended dose x 0.67	Recommended dose x 0.33

Note: For example, if the recommended dose of N for irrigated maize is 150 kgs/ha and if the nutrient content of the soil is very low, then we need to add 250 kg/ha (150 x 1.67), for low 200 kgs/ha (150 x1.33), for medium 150 kgs/ha (150 x 1.0), for high 100 kgs/ha (150 x 0.67; 2/3 general recommendation as per POP) and for very high 50 kgs/ha (150 x 0.33; 1/3 general recommendation as per POP). Similarly, for phosphorus and potassium, the fertilizer requirements are calculated using the above formula.

Table 5.5 General recommended doses of Micronutrients and Sulphur fertilisers

Micronutrients	Critical limits ppm (DTPA extractable)	Dry or Irrigated	Elemental Micronutrient recommended kgs/Ha	Micronutrient fertiliser and quantity for application (kg/ha)	
				Soil application	Foliar spray
Zinc	0.6 ppm	Dry	3.15	Zinc Sulphate.$7H_2O$ 10	0.5% Zinc Sulphate $7H_2O$+0.25% lime
		Irrigated	5.25	25	do
Iron	4.5 ppm	Dry	1.90	Ferrous Sulphate 10	1% Ferrous Sulphate + 0.5% lime
		Irrigated	4.75	25	do
Copper	0.2 ppm	Dry	1.20	Copper Sulphate 5	0.1% Copper Sulphate + 0.05% lime
		Irrigated	2.40	10	do
Manganese	2.0 ppm	Dry	3.05	Manganese Sulphate 10	1% Manganese Sulphate+ 0.25% lime or 0.5% Manganese Sulphate 3 sprays
		Irrigated	7.62	25	do
Boron	0.5 ppm	Dry	0.53	Borax 5	0.25% Borax
		Irrigated	1.05	10	do
Sulphur	10.0 ppm	Dry	20	S @ 20	
		Irrigated	20	40	do

Note: Dominantly used micronutrient fertiliser is indicated in the fertiliser column.

Table 5.6 Nutrient content of Fertilizers (% by weight)

S. No.	Name of fertilizer	N (%)	P_2O_5 (%)	K_2O (%)	S	Zn	B	Mo	Cu	Fe or Mn	Ca or Mg
Nitrogenous Fertilisers											
1	Ammonium Sulphate	20.5			23						
2	Urea (46% N), Super granulated, granular and neem coated urea	46									
3	Ammonium Chloride	25									
4	Calcium Ammonium Nitrate	25									
5	Urea Ammonium Nitrate (32%N) (liquid)	32									
6	Sulphur Coated Urea	37			17						
Phosphatic Fertilisers											
7	Single Super Phosphate (16% P2O5 Powdered & granular)		16		14.5						
8	Triple Superphosphate		46								
9	Rock Phosphate		18								
10	Super phosphoric Acid (70% P2O5 (Liquid)		70								
Potassic Fertilisers											
11	Potassium Chloride (Muriate of Potash)- powder and granular			60							
12	Potassium Sulphate			50	17.5						
13	Potassium Schoenite			23							
14	Potash Derived from Molasses			14.5							
15	Sulphur 90% (Powder and Granular)				90						
N.P. Complex Fertilisers											
16	Diammonium Phosphate (18-46-0)	18	46								
17	Ammonium Phosphate Sulphate (16-20-0)	16	20		13						
18	Ammonium Phosphate Sulphate (20-20-0)	20	20		13						
19	Nitro Phosphate (20-20-0)	20	20								
20	Urea Ammonium Phosphate (28-28-0)	28	28								
21	Urea Ammonium Phosphate (20-20-0)	20	20								
22	Mono Ammonium Phosphate (11-52-0)	11	52								
23	Ammonium Nitrate	23	23								

	Phosphate (23-23-0)										
24	Ammonium Poly-phosphate (10-34-0) (Liquid)	10	34								
25	Ammonium Phosphate (14-28-0)	14	28								
26	NPS 13:33:0:15S	13	33		15						
27	Nitro phosphate (24-24-0)	24	24								
NPK Complex Fertilizers											
28	Nitro phosphate with Potash (15-15-15)	15	15	15							
29	N.P.K. (10-26-26)	10	26	26							
30	N.P.K. (12-32-16)	12	32	16							
31	N.P.K. (22-22-11)	22	22	11							
32	N.P.K. (14-28-14)	14	28	14							
33	N.P.K. (19-19-19)	19	19	19							
34	N.P.K. (17-17-17)	17	17	17							
35	N.P.K. (20-10-10)	20	10	10							
36	N.P.K. (15:15:15)	15	15	15							
37	N.P.K. (15:15:15:9(S))	15	15	15	9						
38	N.P.K. (12:11:18)	12	11	18	7.5						
39	N.P.K. (16:16:16)	16	16	16							
40	N.P.K (9:25:25)	9	25	25							
41	Nitro phosphate with Potash (14:14:21)	14	14	21							
42	Nitro phosphate with Potash (21-06-13)	21	6	13							
43	Nitro phosphate with Potash Grade II (15-15-15)	15	15	15	3.5						
44	Nitro phosphate with Potash Grade II (15-9-20)	15	9	20	3.5						
Micronutrient containing Fertilisers											
45	Sulphur 90% (Powder)				90						
46	Sulphur 90% (Granular)				90						
47	Zinc Sulphate Heptahydrate (ZnSO47H2O)				10	21					
48	Zinc Sulphate Mono-hydrate (ZnSO4.H2O)				15	33					
49	Manganese Sulphate				17					Mn 30.5	
50	Borax (Sodium Tetraborate) (Na2B4O7.10H2O) for Soil Application						10.5				
51	Copper Sulphate (CuSO4.5H2O)				12				24		
52	Ferrous Sulphate (FeSO4.7H2O)				10.5					Fe 19	
53	Ammonium Molybdate (NH4)6Mo7O24 .4H2O							52			

54	Chelated Zinc as Zn-EDTA					12					
55	Chelated Iron as Fe-EDTA									Fe 12	
56	Magnesium Sulphate				12						Mg 9.5
57	Boric Acid (H3BO3)						17				
58	Di-Sodium Octa Borate Tetra Hydrate (Na2B8O13.4H2O)						20				
59	Di-Sodium Tetra Borate Penta Hydrate (Granular)						14.5				
60	Zinc Oxide Suspension Concentrate (39.5% Zn)					39.5					
61	Di-Sodium Tetra Borate Penta Hydrate						14.5				
62	Anhydrous Borax (Na2B4O7)						20.5				
Fortified Fertilizers											
63	Boronated Single Superphosphate (16% P2O5 Powdered)		16		14.5		0.3				
64	Zincated Urea	43				2.0					
65	Zincated Phosphate (Suspension) – for Seed Treatment		14			17.5					
66	Boronated NPK Complex (10:26:26)	10	26	26			0.3				
68	Boronated NPK Complex (12:32:16)	12	32	16			0.3				
67	Boronated Diammonium Phosphate (18:46:0)	18	46				0.3				
68	Zincated NPK Complex	10	26	26		0.5					
69	Zincated NPK Complex (12:32:16)	12	32	16		0.5					
70	Boronated Calcium Nitrate	14.5					0.3				
71	Boronated Nitro phosphate with Potash (15:15:15)	15	15	15			0.3				
72	Zincated DAP (18:46:0)	18	46			0.5					
73	Zincated SSP (16% P2O5)		16		11	0.5					
74	Bononated NPK Complex (24:24:0)	24	24				0.3				
75	Zincated Bentonite Sulphur				65	18					
76	Zincated Urea Ammonium Phosphate 28-28-0	28	28			0.5					
77	NP 24-24-0 fortified with Sulphur	24	24		8						
78	Boronated Ammonium Phosphate Sulphate	20	20		13		0.3				
100 % Water Soluble Complex Fertilisers											

79	Potassium Nitrate (13-0-45)	13		45							
80	Mono-Potassium Phosphate (0-52-34) (100% water soluble		52	34							
81	Calcium Nitrate	14.5									Ca 18.5
82	Potassium Magnesium Sulphate			22	20						Mg 18
83	Mono Ammonium Phosphate 12:61:0 (100% water soluble)	12	61								
84	Urea Phosphate 17:44:0 (100% Water Soluble)	17	44								

Among the list of fertilisers provided in the Table 4.5, only few fertilisers are used extensively by the farmers of the state and others are used in less extent. The major fertilisers that are widely used in the state are indicated below.

1. Diammonium Phosphate (18-46-0)
2. Urea (46% N) in different forms like Super granulated, granular and neem coated urea
3. Ammonium Phosphate (20-20-0)
4. Potassium Chloride (Muriate of Potash)- powder and granular form
5. N.P_2O_5 K_2O (10-26-26)
6. Single Super Phosphate (16% P2O5)

Major fertiliser combinations widely used in the state are indicated below

1. Diammonium Phosphate (18-46-0), Urea, Single Super Phosphate (16% P2O5), Potassium Chloride (Muriate of Potash)
2. Ammonium Phosphate (20-20-0), Urea, Single Super Phosphate (16% P2O5), Potassium Chloride (Muriate of Potash)
3. N.P_2O_5 K_2O (10-26-26), Urea, Single Super Phosphate (16% P2O5), Potassium Chloride (Muriate of Potash)
4. Urea, Single Super Phosphate (16% P2O5), Potassium Chloride (Muriate of Potash)

The development of Decision Support System for nutrient management will provide the required amount of nutrients needed for the selected crop based on the combination of the above five fertilisers which are readily available and extensively used at present in the state. If all possible combination of fertilisers (as per the list of fertilisers) available for each crop has to be worked out and shown as an output from this DSS, then the list of combination becomes too many for each crop, which in turn will make it difficult for the farmer to select the combination that is best suited for the crop.

In case if a farmer or any other user is interested to use any other fertiliser or combination of fertilisers other than the five important and readily available fertilisers as indicated above then he or she can choose the input option provided in the DSS to get the output.

Table 5.7 Rates of Fertilizers

Sl No.	Name of Fertilizer	Rate of fertilizer after GST for 50 kg bag (Rs/Kg)	Rate per kg fertilizer (Rs/Kg)
1	Diammonium Phosphate 18-46-0	1400	28.00
2	N.P. Complex 20-20-0	1040	20.80
3	N.P.K. Complex 10-26-26	1340	26.80
4	Urea 46 % N	295	5.90
5	Muriate of Potash 60 %K2O	949	18.98
6	Single Super Phosphate 16 %P2O5	545	10.90
7	N.P. complex16-20-0	905	18.10
8	N.P. complex 24-24-0	1150	23.00
9	N.P. complex 28-28-0	1275	25.50
10	Ammonium Sulphate 20.5% N	1015	20.30
11	N.P.K. complex 15-15-15	987	19.74
12	N.P.K.complex 17-17-17	1066	21.32
13	N.P.K.complex 19-19-19	1178	23.56
14	N.P.K.complex 12-32-16	1350	27.00
15	N.P.K. complex 14-35-14	1275	25.50
Micronutrients			
1	Zinc Sulphate 7H2O (Zn)		45.00
2	Borax (B)		70.00
3	Ferrous Sulphate (Fe)		20.00
4	Manganese Sulphate (Mn)		25.00
5	Copper Sulphate (Cu)		100.00
6	Gypsum (S)		3.80

Source: Department of Agriculture, 2018

Table 5.8 Step-by-step process to provide nutrient management advisories to farmers

Step	Description
1	Read farmers information (Contact number, land parcel, crop sown, area, ACZ, dry or irrigated)
2	Read soil fertility status with respect to land parcel from LRI information
3	Select nutrient recommendation from selected crop
4	Adjust nutrient recommendation with respect to soil fertility status
5	Read nutrient content in fertilizers
6	Estimate amount of fertilizer required for the crop
7	Estimate the dose at different stages of plant growth (Basal dos and top dressing)
8	Send the advisory to the farmer-dosage of fertilizer and cost at different stages of growth along with package of practices to be followed
9	Based on the nutrient status of the soil in the watershed/sub watershed area estimate the amount of fertilizers required for the area.

Note: Watershed/sub watershed wise (area wise) fertilizer requirement can be indicated in a separate flow chart if necessary

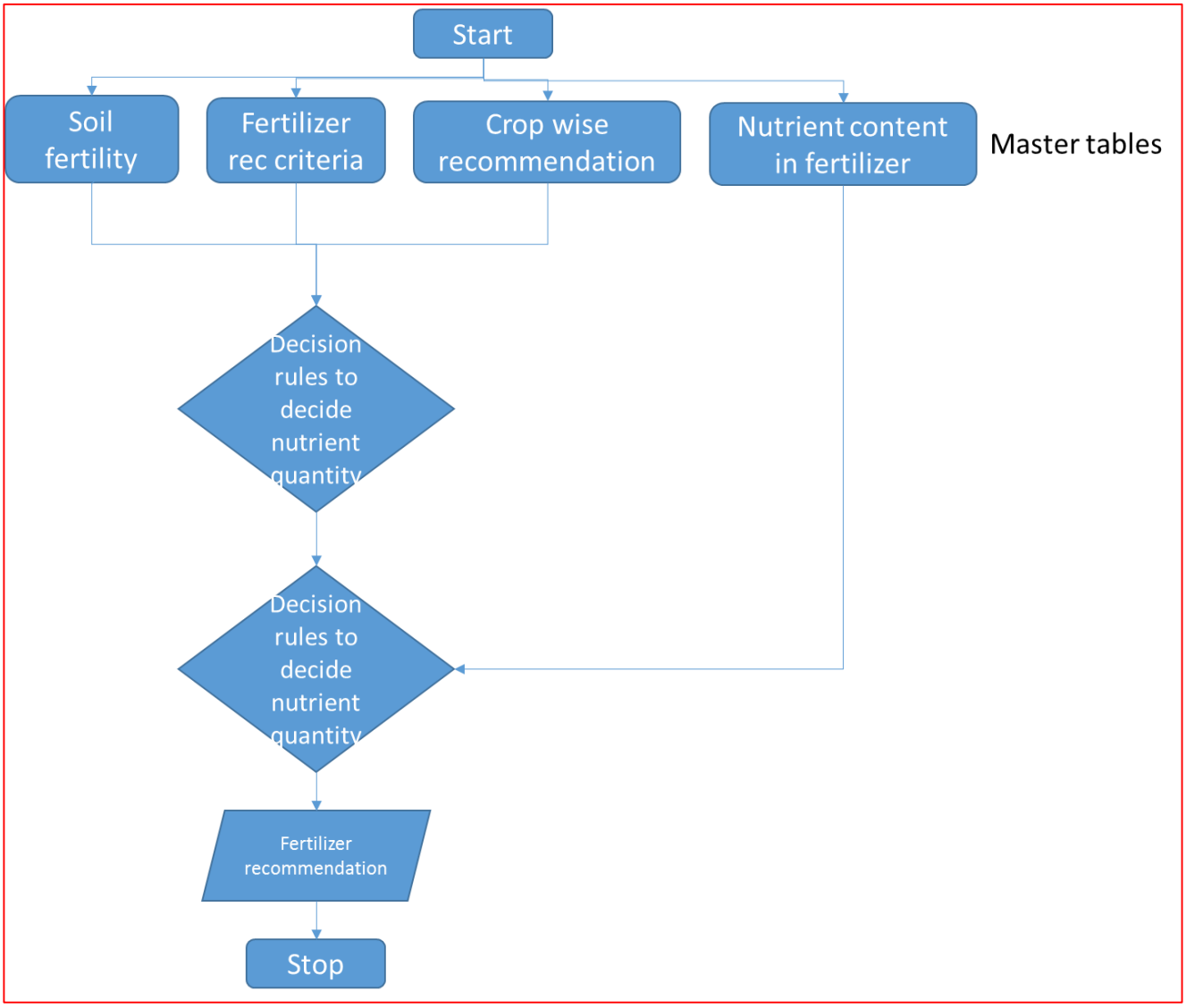

Figure 5.1 Flow diagram for deciding crop wise fertilizer management-as provided in the FRS

Module Description for the execution of the DSS on Nutrient Management

After successful login, user will click on 'Nutrient Management' under Decision Support System. A web page for Nutrient Management DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number, Crop Name, Season and Practice. The details of input fields in Web page are as mentioned in section**Error! Reference source not found.**. "From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will auto fill the District, Taluk, Village and Survey number values.
- User will be able to select the District, Taluk, Village, Survey Number, Season, Crop Name, and Practice (dry or irrigated)
- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- Select Values such as Nutrient parameters, soil characteristics from Land Parcel characteristic table against the respective Cadastral ID.
- Execute a query on "DSS4_Soil_Fertility_Macro_nutirent" and check the fertility status of macronutrient, OC, N, P, K, S.
- Get the recommended nutrient for selected crop and practice by executing query on "Cropwise_Fertiliser_Recommendation"
- Depending upon the Nutrient status adjust the nutrient values by executing query on "DSS4_Macro_Nutrient_adjustment".
- Get the list of recommended fertilizers by executing query on "Nutrient_Content_of Fertilizer".
- Execute Query on DSS4-Organic_Manure, DSS4_Bio_Fertilizer, DSS4_Basal_Dose, DSS4_Top Dress Fertilizers, to get the required recommendation using the Crop selected.
- Display the result in a table showing the information such as Survey NO, Farmer Name, Area In Hectare, Crop Name, Bio-Fertilizers Gm/Ha, Organic Manure Tn/Ha, Fertilizer Required, Total Quantity in Kg (A), Basel Dose Kg(B), Top Dressing Kg C= (A-B), Total Cost for fertilizer C * unit cost, POP.
- Display the package of practice document for the crop selected from result grid view.
- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that particular user session which will help to further execute and analyze DSS results based on these temporary changes.
- Option will be provided to select other fertilizer or combination of fertilisers other than the five important and readily available fertilisers to get the output

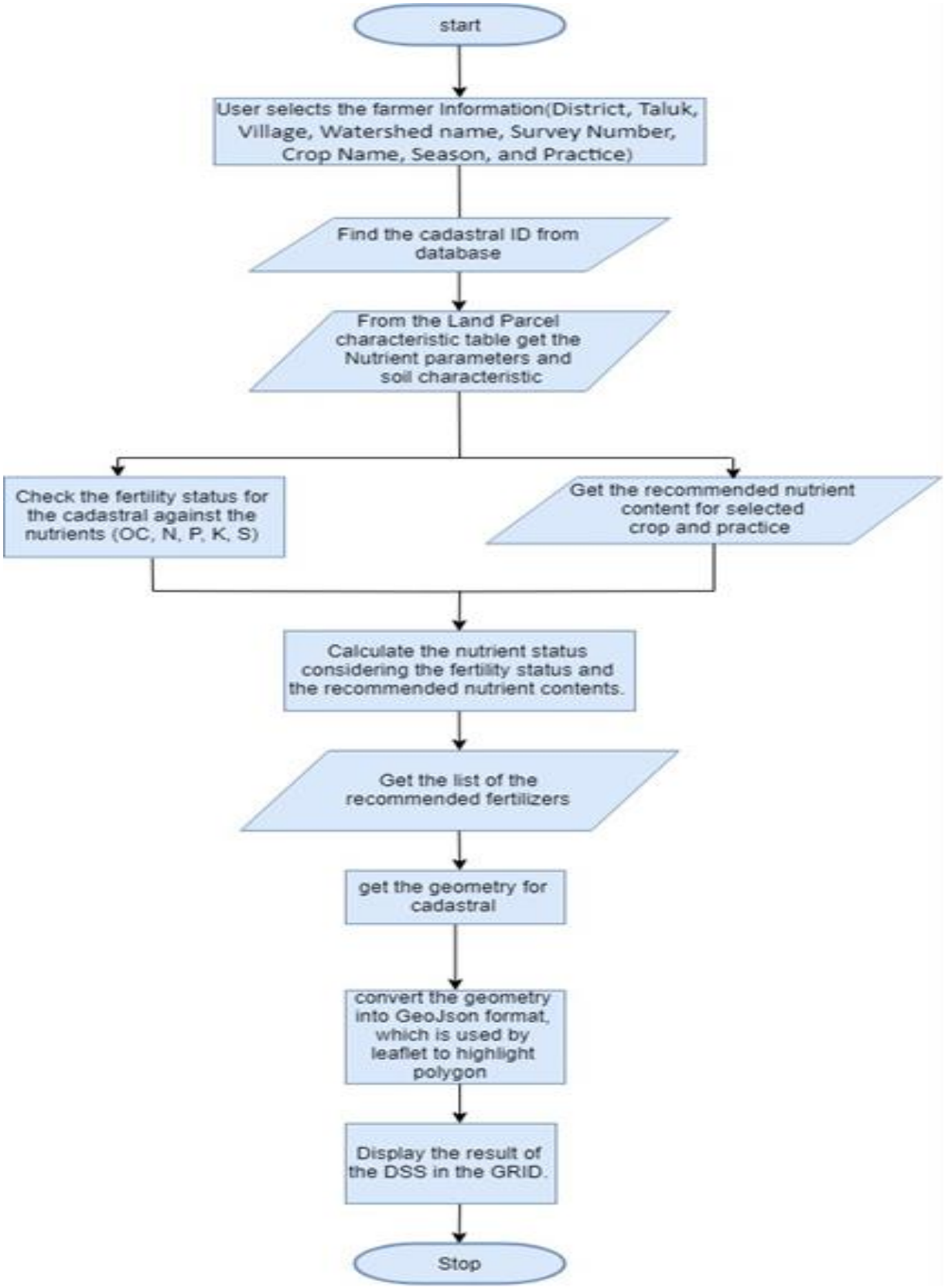

Fig.5.2 Flow chart for the development of DSS on Nutrient management as per the LLDD

Survey number wise DSS Outputs and Reports for Macro nutrients (NPK)

Survey No.	Area (Ha.)	Crop	$N.P_2O_5$ K_2O recommended as per package of practices	$N.P_2O_5$ K_2O recommended as per soil test values	Fertilisers selected	Combination of fertilisers	Basal dose	Top dressing	Total cost	POP

Note: Fertiliser recommendation per acre = Fertiliser recommendation per Ha x 0.4, Farmers details can be provided in another table.
The report can show the survey number wise fertiliser requirements and total cost required for the major crops cultivated in the watershed area.

Survey number wise DSS Outputs for Micronutrients (Only for deficient soils, irrespective of the crop to be applied) in Kgs/Ha. This table can be merged with the above table

Survey No.	Name of Farmer	Area (Ha)	Crop	Sulphur	Zinc	Iron	Boron	Manganese	Copper	Calcium	Magnesium
Rain fed crops											
				Gypsum 140	Zinc Sulphate 7H2O-10	Ferrous Sulphate 10	Borax 5	Manganese Sulphate 10	Copper Sulphate 5		
Irrigated crops											
				280	25	25	10	25	10		

Note: Fertiliser recommendation per acre = Fertiliser recommendation per Ha x 0.4, Blanket recommendation for all the crops

Note: Requirement of Macro nutrients (NPK) at watershed level: Apart from the display of the nutrient status maps, the amount of nutrients required for the Micro watershed/sub watershed area can be estimated and shown as an output as per the requirement.

Nutrient status[1]	Extent of area (Ha or acres) under each nutrient								
	N			P			K		
	Area	Factor	Total Nutrients required	Area	Factor	Total Nutrients required	Area	Factor	Total Nutrients required
Very high									
High									

Medium									
Low									
Very low									
Total nutrients needed									

Note:

- For the area under **Very High nutrient status** in a watershed, the area is multiplied with 0.33 to get the nutrient requirement (Total area under very high-status x 0.33)
- For the area under **High nutrient status**, the area is multiplied with 0.67 to get the nutrient requirement (Total area under high status X 0.67)
- For the area under **Medium nutrient status**, it is multiplied with the average of the medium value as given in the Table 4.1(Total area under medium status X average of the medium nutrient status)
- For the area under **Low nutrient status**, it is multiplied with the average of the medium value as given in the Table 4.1(Total area under medium status X 1.33 of the average medium nutrient status)
- For the area under **Very low nutrient status,** it is multiplied with the average of the medium value as given in the Table 4.1(Total area under medium status X 1.67 of the average medium nutrient status)
- Based on the total amount of nutrients required and the quantity and combination of major fertilisers can be displayed at the micro watershed level.

Nutrient status[1]	Extent of deficient area under each micronutrient (Ha) x quantity of micronutrient recommended (Kgs/Ha)								
	S	Zn	B	Mo	Cu	Fe	Mn	Ca	Mg
Deficient area in Ha									
Total amount of micronutrients required for the watershed (Kgs)									

Sub watershed level DSS Outputs and Reports: Aggregation of the nutrient requirements and combination of fertilisers from all the micro watersheds can provide the requirements at the sub watershed level.

Chapter 6

DSS for estimating Runoff at farm, map unit, MWS, SWS and higher levels

When rainfall occurs in excess of absorption by soil, it causes runoff which increases with time and length of slope. Runoff is influenced by multiple factors like intensity and duration of rainfall, initial abstraction, existing land use, slope gradient and length, rate of infiltration, percolation rate, presence of hard substratum, antecedent moisture, management practices and other factors.

Runoff is a critical factor in deciding the type of conservation needed, number and location of water harvesting and recharge structures, formulation of appropriate cropping pattern and crop selection and the water balance and water availability at the watershed scale.

Some important runoff estimation models that are in use are SCS Curve Number method, which is an empirical method of estimating excess precipitation, Constant infiltration based method in which saturated soil conductivity is used as infiltration rate; Horton equation, which is based on mathematical equation; SAC-SMA (Sacramento Soil Moisture Accounting) which attempts to mimic physical constraints of water movement in a natural system, many other models and Rational method (Ramser's method).

Under this DSS, along with the SCS Curve Number and Rational methods, Runoff model developed based on LRI database (Infiltration) and precipitation available from KSNMDC is included to estimate the amount of runoff that can be expected to occur at different levels in a watershed area.

i) SCS Curve Number method

Following is the example of estimation of daily runoff using SCS Curve number method. Ref: http://www.isprs.org/proceedings/XXXVII/congress/2_pdf/1_WG-II-1/11.pdf

Table 6.1: Input parameter required for runoff estimation under SCS Curve Number method

Required input	Master table/map	Derived data	Remark
Land use/ cropping pattern	Land use/ cropping system- from land use maps		Data from the land use map generated by LRI, or using remote sensing
Soil texture	Management unit wise (soil phase) texture data	Characterization of soil in four hydrological groups- not done under LRI	
Infiltration rate	Soil phase wise infiltration rate		
Land slope	Soil phase wise Slope		

Curve numbers		Curve numbers for different combinations of Land cover/use classes and soil hydrological groups	
Rainfall	Daily rainfall data	Daily rainfall, 5-day antecedent rainfall	

Table 6.2: Step-by-step processes for runoff estimation under SCS Curve Number method (Fig.6.1).

Steps	Description
1	Read **Soil phase** wise Land use-land cover/use classes
2	Read Soil phase wise soil hydrological groups
3	Decide curve number for each Soil phase based on land cover/use class and soil hydrologic group (AMC-II)
4	Check 5-day antecedent rainfall with AMC condition AMC- I: Lowest runoff potential. The soils are dry enough for satisfactory cultivation (rainfall < 35 mm) AMC- II: Average condition (rainfall between 35 to 52.5 mm) AMC- III: Highest runoff potential. The area is practically saturated from antecedent rains (rainfall > 52.5 mm)
5	Select multiplication factor to Convert Curve Number for AMC II to AMC I or III
6	Adjust the curve number using AMC factor
7	Estimate the potential maximum soil moisture retention after runoff begins and initial abstraction factor using adjusted curve number
8	Estimate runoff using daily rainfall, the potential maximum soil moisture retention after runoff begins and initial abstraction
9	Display runoff at different levels from survey number, management unit, MWS, SWS and higher levels

Note: Display of results at SWS and higher levels is not possible at present due to the change in land use at each survey number. It will be available from all the three methods from survey number and soil unit levels at present. From infiltration method, results can be provided at any levels as per the requirement.

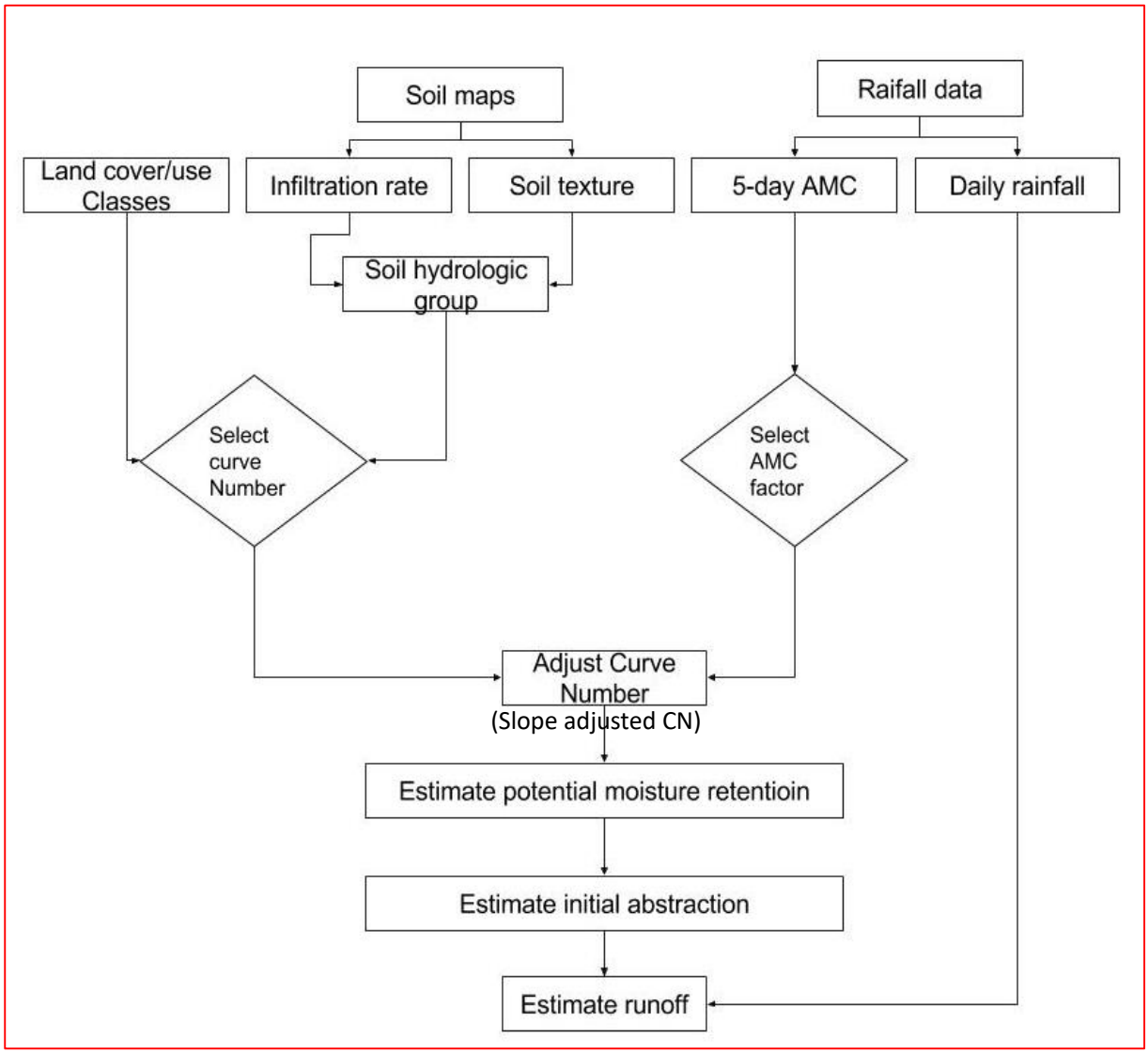

Figure 6.1: Flow diagram for estimating runoff: (Note: infiltration rate is estimated for *major* soils identified in the watershed areas) based on CN method, as provided in the FRS

Table 6.3: Master table of curve numbers based on land cover/use and hydrologic soil groups

Land cover	Hydrologic soil groups*			
	A	B	C	D
Forest	30	43	60	63
Cropped area (Good crop, Fair crop, Poor crop)	71	77	84	86
Fallow	77	86	91	94
Settlement	75	85	90	91
~~Uncultivable~~				
Water body	0	0	0	0

Table 6.4 Multiplication factor for converting AMC II to AMC I or III

Curve Number (AMC II)	Factors to Convert Curve Number for AMC II to AMC I or III	
	AMC I (dry)	AMC III (wet)
10	0.4	2.22
20	0.45	1.85
30	0.5	1.67
40	0.55	1.5
50	0.62	1.4
60	0.67	1.3
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1	1

Runoff based on CN method:

Survey Number	Rainfall (mm)	Surface runoff (mm)	Surface runoff (Cum)	Remarks
Soil unit				
Micro watershed				

Execution of Runoff Modules as elaborated in the LLDD

After successful login, user will click on 'Surface Runoff' under Decision Support System. A web page for Surface Runoff DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number, and Runoff Model. The details of input fields in Web page are as mentioned in section. From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will autofill the District, Taluk, Village and Survey number values.
- User will select the District, Taluk, Village, Micro Watershed, Survey number and Runoff model.
- Depending upon the Runoff model selected by the user

SCS Curve Number method:

- If user select the SCS
- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- Get the Soil texture, Slope, Landform (Black, Red / lateritic) from the Parcel characteristics table for the respective cadastral ID.
- Based on the selection of District, Taluka, Village and Survey no., the slope and the soil texture will be obtained.
- Hydrological Soil group (HSG) will be selected based on the below mentioned table.

HSG	Soil texture
• A	• Sand, loamy sand and sandy loam
• B	• Silt loam or loam
• C	• Sandy clay loam
• D	• Clay loam, silt clay loam, sandy clay, silty clay or clay

- From current land use (CLU) the crop type, the quality of the crop (Good/Poor/Fair crop) will be obtained (Dominant crop or land use to be considered).

- Depending on CLU and HSG, the Curve Number (CN) will be selected from the table mentioned below.

Current Land Use (CLU)	Hydrologic Soil Groups (HSG)			
	A	B	C	D
Forest	30	43	60	63
Good crop[1]				
Fair crop	71	77	84	86
Poor crop				
Fallow land	77	86	91	94
Settlement	75	85	90	91
Waterbody	0	0	0	0

Note: HSG table is considered same as in FRS (Table 52). [1]Revised in the meeting held on 23.05.2019 at WDD with inputs from Dr.U Satish Kumar, UASR.

5-day antecedent rainfall will be checked with Antecedent Moisture Condition (AMC).

a. AMC I: If the rainfall is < 35mm, then the soil is dry for satisfactory cultivation, i.e. lowest runoff potential

b. AMC II: If the rainfall is between 35mm to 52.5mm, then the soil is considered as average for satisfactory cultivation

c. AMC III: If the rainfall is > 52.5mm, then the soil is saturated from the antecedent rains, i.e. highest runoff potential.

- The Multiplication Factor will be selected from the below mentioned table depending on AMC condition (AMC I/AMC II/AMC III). This will convert CN for AMC II to AMC I or AMC III. This will adjust the curve number.

CN (AMC II)	Factors to convert CN for AMC II to AMC I or II	
10	0.4	2.22
20	0.45	1.85
30	0.5	1.67
40	0.55	1.5
50	0.62	1.4

60	0.67	1.3
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1	1

Note: Multiplication Factor for converting AMC II to AMC I or III table is considered same as in FRS (Table 52).

- Adjust the obtained Curve Number (only for CN III) according to the slope, hence it is termed as Slope Adjusted Curve Number (SACN). (Ref: Deshmukh et.al, 2013: Estimation and Comparison of Curve Numbers Based on Dynamic Land use Land Cover Change, Observed Rainfall-Runoff Data and Land Slope).

$$SACN_2 = \frac{1}{3}(CN_3 - CN_2) - (1 - 2e^{-13.86\alpha}) + CN_2$$

Where,

$SACN_2$ - Slope adjusted CN for AMC II
CN_2 - CN for antecedent soil moisture condition II
CN_3 - CN for antecedent soil moisture condition III
α - Soil slope (m/m)

- If the slope is similar in the selected parcel area, then only one value of SACN2 is valid for that parcel. But if two or more slope values are found in a parcel then weighted average value of (SACN2) W is calculated as mentioned below.

$$(SACN_2)_W = \frac{A_1(SACN_2)_1 + A_2(SACN_2)_2 + \ \ldots\ldots\ldots\ldots A_n(SACN_2)_n}{A_1 + A_2 + \ \ldots\ldots A_n}$$

Where,
$(SACN_2)_1$, $(SACN_2)_2$ …….. $(SACN_2)_n$ are Slope adjusted CN for AMC II for different elevations of size A_1, A_2 …… A_n in hectares respectively.

- After this, estimation of Potential Maximum Soil Moisture Retention of Runoff (Pe) and Initial Abstraction (Ia) factor using Slope Adjusted Curve Number are done.

$$S = \frac{1000}{SACN_2} - 10 \text{ x (25.4 to convert inches to mm)}$$

Where,
S – Potential Maximum Soil Moisture Retention (in mm)
$SACN_2$ - Slope Adjusted CN for AMC II

- Estimation of Initial Abstraction is done using following equation depending on the Soil texture and AMC.
    - For black soil region (AMC I) and Red soil/Laterite soil region (AMC I, AMC II, & AMC III):

$$I_a = 0.3\ S$$

    - For black soil region (AMC II & AMC III):

$$I_a = 0.1\ S$$

Where, (units to be in mm)

I_a – Initial Abstraction (in mm

S - Potential Maximum Soil Moisture Retention (in mm)

Note: Instead of black soil type, consider 5 Clay bounds namely clay, silty clay, clay loam, silty clay loam and sandy clay loam. Instead of red/laterite soil type, consider 7 Sand bounds namely sandy clay, sandy loam, loamy sand, sand, silt loam, loam and silt.

- Finally, Runoff is estimated using Daily Rainfall, Potential maximum Soil Moisture Retention, Initial Abstraction. (Ref: Garg et al., May 2016, A simple and farmer-friendly decision support system for enhancing water use efficiency in agriculture: tool development, testing and validation)

For Rainfall ≥ Initial Abstraction,

$$P_e = \frac{(P - I_a)^2}{(P - I_a + S)}$$

Else, Zero.

Where,

P_e – Runoff (in mm)

P – Rainfall (in mm)

I_a – Initial Abstraction (in mm)

S - Potential maximum Soil Moisture Retention (in mm)

Output will be converted from inches to mm by multiplying the obtained value by 25.4

- Display the result in a table showing the information such as Survey No, Farmer Name, Area in Hectare, Interval, Runoff (mm) and volume of runoff in cu.m.
- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.

Note: Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

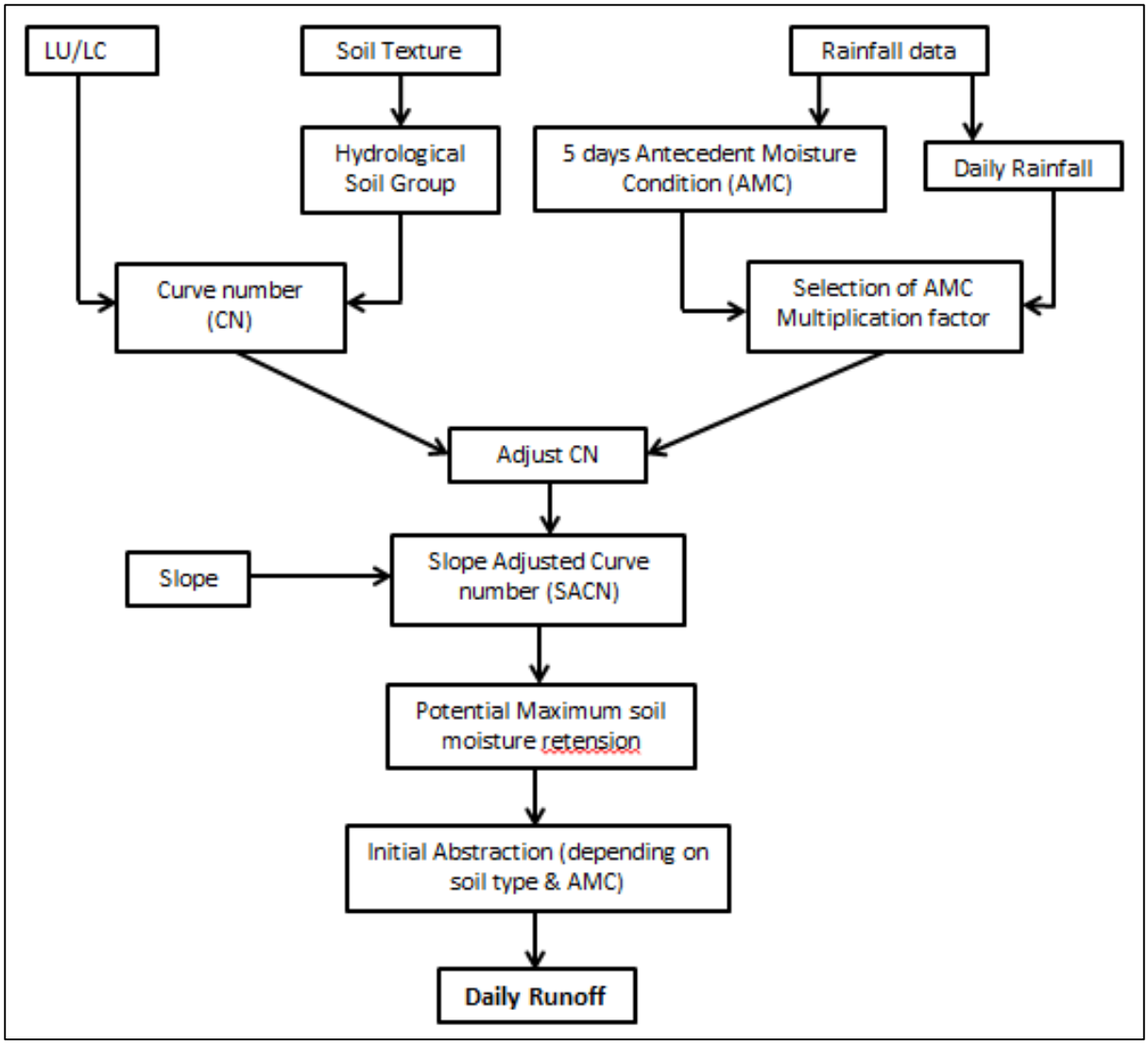

Figure 6.2 Flow chart for estimating runoff based on CN method, as per LLDD

Survey number wise DSS Outputs and Reports

Survey number	Farmer details	Area (Ha & Acres)	Daily Rainfall (KSNDMC)	Daily Runoff mm	Runoff (Cum/Ha) or for the total area	Remarks

Runoff at soil unit wise, MWS and SWS levels

MWS	Soil unit	Area (Ha & Acres)	Daily Rainfall (KSNDMC)	Daily Runoff mm	Runoff (Cum) for the soil unit or for the MWS	Remarks

Note: - For soil unit wise, MWS and SWS levels calculation of runoff, Curve number will be derived using weighted average based on respective curve numbers of land use, hydrological group, and slope.

ii) Runoff by <u>Rational method</u> (Ramser's method).

The return period, also known as recurrence interval or frequency is defined as the period of years during which a rainstorm of a given duration and intensity is expected to occur. This method is used to design water harvesting structures, except farm ponds, at the watershed and higher levels. Recommended return period or rainfall frequency for various types of structures is given in Table.6.5.

Table 6.5 Recurrence interval for different conservation structures

Type of structure	Frequency of occurrence (years)
Storage and diversion dams having permanent spillways	50-100
Earth fill storage dams having natural spillways.	25-50
Stock water dam (Nala bund, Check dam, Percolation tank & Vented dam)	25
Small permanent masonry gully control structure and silt retention structure (Ravine reclamation structure)	10
Bunds, Water ways, Farm ponds & Diversion channel.	10

Two methods are used for estimating peak rate of runoff, namely Ramser's or Rational method. The most widely used method is the Rational method and is the oldest, simplest and possibly the most consistent one in its ability to adapt to new concepts and developments in conservation programmes.

Rational Formula $Q = CIA/360$,

Where,

'Q' is peak rate of runoff (Cubic meters per second)

'C' is runoff coefficient (Table 6.6)

'A' is area of catchment (hectares)

'I' is intensity of rainfall for the design frequency and for duration equal to time of concentration of the watershed/catchment. (mm/hr.). Highest rainfall intensity of a day observed in about 10 years' time period or whatever years data is available from KSNDMC.

The runoff coefficient, C is a dimensionless quantity giving the ratio of peak runoff rate to the rainfall intensity. It is influenced by the soil type, topography and land use. If there is homogeneous condition only one value of C will be valid. If there is heterogeneous condition, weighted value of C should be calculated using the formula:

$$C_w = A_1C_I + A_2 C_2 + \ldots\ldots A_n C_n/A$$

Where, A is the total area of the watershed, C_1, $C_{2,}$….,Cn are the coefficients of runoff for the different homogeneous areas of size A_1,A_2….. A_n ha respectively.

Table 6.6'C' Values for use in Rational formula

Land Use & Slope (%)	Soil Texture		
	Sandy loam	Clay & Silt Loam	Clay
1. Cultivated Land			
0-5	0.30	0.50	0.60
5-10	0.40	0.60	0.70
10-33	0.52	0.72	0.82
2. Pastureland			
0-5	0.10	0.30	0.40
5-10	0.16	0.36	0.55
10-33	0.22	0.42	0.60
3. Forest Land			
0-5	0.10	0.30	0.40
5-10	0.25	0.35	0.50
10-33	0.30	0.50	0.60

Source: *Gurmel Singh, Venkataraman, C., Sastry, G. and Joshi, B.P., 1981, Manual of soil and water conservation practices in India, Oxford and IBH Publication, 439 pp.*

Rainfall Intensity

Available rainfall intensity is used for calculation of the intensity for a given duration of a particular recurrence interval is considered. Wherever rainfall intensity data are not available calculation of the intensity for a given duration of a particular recurrence interval involves the following steps

For Slope= $(\Delta H / L)*100$ in %

ΔH=Slope * L/100

Where ΔH is difference in elevation in meters

L is maximum length of the flow in meters

Step I: Determination of Time of concentration (T_C)

Time of concentration (Tc) of a watershed is defined as the time taken by the water to flow from the remotest point of the watershed to the outlet. If data is available, they are directly used. If not, it is calculated using the following procedure.

$Tc = 0.01947\ K^{0.77}$ where $K = \sqrt{\frac{L^3}{H}}$

Where L = Length from remote point to the point of interest or point of concentration (m).

H = Fall between the remote point and the point of interest/outlet (m)

Tc = Time of concentration in minutes

Intensity of rainfall (I) for the desired frequency or recurrence interval and for a duration equal to time of concentration is worked out as follows.

$I = \frac{K_1 T^{a}}{}$

$(b+Tc)^n$

Where: K_1, a, b and n. are empirical

Constants to be selected from Table:6.7

Tc = Time of concentration in hours (Tc in minutes/60 = Tc in hours)

T = Recurrence interval or frequency (years)

Table:.6.7 Rainfall intensity – duration – return period relationship & Empirical constants

Meteorological Station	Agro-climatic Zone	K_1	a	b	n
1. Bangalore	1. Southern Dry zone 2. Eastern Dry Zone	6.275	0.1262	0.5	1.1280
2.Hyderabad	3. Northern Dry Zone 4. North eastern Dry Zone 5. Central Dry Zone	5.250	0.1354	0.5	1.0295
3. Mangalore	6. Coastal Zone	6.744	0.1395	0.5	0.9374
4.Other Zones	7. Southern transition Zone 8. Northern transition Zone 9. North eastern transition Zone 10.Hilly Zone	6.311	0.1523	0.5	0.9465

Source: *Gurmel Singh, Venkataraman, C., Sastry, G. and Joshi, B.P., 1981, Manual of soil and water conservation practices in India, Oxford and IBH Publication, 439 pp.*

Note: 1. Using the QUICK BIRD/other Satellite imageries, the remote points of first order and point of interest are marked, their elevations are known and also length of runoff flow can be arrived.

2. Empirical constants K1, a,b & n needs updating for different Meteorological stations established in the state.

Example: Calculate Intensity of Rainfall 'I' for design of a check dam proposed in Nanjanagud taluka. The check dam has a catchment of 40 hectares, the distance from farthest ridge point to the structure is 2500 m. and reduced levels are 95.00 and 45.00 m. respectively.

Data **:** 1. Catchment: 40 hectares

2. Fall: (95.00 – 45.00) = 50.00 m.

3. Length of travel: 2500 m

4. Empirical constants:

Nanjanagud is in Southern Dry Zone, therefore the constants to be considered are

K = 6.275

a = 0.1262

b = 0.5

n = 1.128

5. Recurrence interval for check dam is 25 years.

Time of Concentration = Tc = $0.01947\ K^{0.77}$

Where $K = \sqrt{\frac{L^3}{H}}$ L = Maximum length of travel in meters = 2500 m
H = Difference in elevation between most remote point and outlet in meters = 50 m.

$$\sqrt{\frac{2.500^3}{50}} = 17678$$

Time of concentration Tc = $0.01947 \times 17678^{0.77}$
= 0.01947×1864.33 = 36.30 minutes
= 0.61 hour.

Intensity of rainfall in cm / hour (I)

From Table 4.1.3

$$I = \frac{KT^a}{(Tc + b)^n}$$

K = 6.275
a = 0.1262
b = 0.50
n = 1.1280
Tc= time of concentration, in hours
= 0.61 hours
T = Return Period (Frequency = 25 years)

$$I = \frac{6.275 \times 25^{0.1262}}{(0.61 + 0.50)^{1.1280}} = \frac{6.275 \times 1.5011}{(0.61 + 0.50) = (1.11)^{1.1280}} = \frac{9.4196}{1.1135}$$

= 8.4595 cm / hour, or
= 84.595 mm / hr.

Time of concentration is a function of length of the main channel (L, in m) and fall in elevation from the remotest point to the outlet (H, in m). It can also be directly read from the nomograph given in fig.1. The values of L and H are connected by a line and the point of intersection of this line on the Tc scale is the time of concentration. For example, if L is 700 m. and H is 5 m, the line connecting H and L will intercept the Tc scale at 0.35 hours to give the time of concentration.

Step II. Determination of one-hour maximum rainfall for the design recurrence interval.
The values of one-hour maximum rainfall for a given locality and chosen recurrence interval are obtained from the rainfall frequency maps of one-hour duration of the country (The data used is 50 years old, needs to be revised).

Step III. Conversion of one-hour maximum rainfall to rainfall intensity for a particular duration (Time of Concentration). Having determined the time of concentration and one-hour maximum rainfall of the watershed as explained above, the rainfall intensity for a particular duration can be determined from the graph given in Fig-5. Knowing the value of one-hour maximum rain fall depicted on the y-axis, move parallel to the X-axis from this point which will give the required value of rainfall intensity (I) for the duration indicated (Time of Concentration).

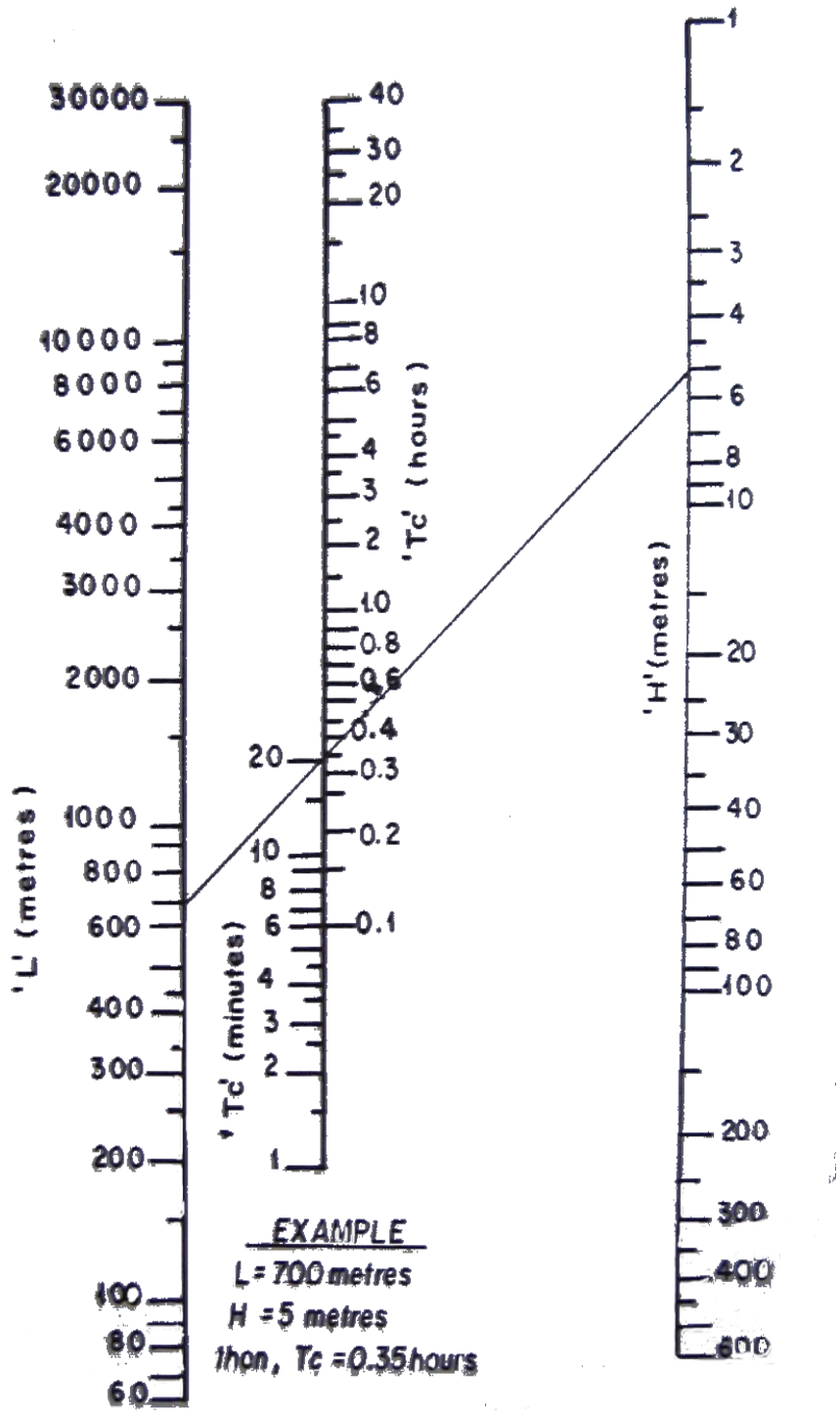

Fig.6.3 Nomograph for estimating time of concentration (Tc)

Source: *Gurmel Singh, Venkataraman, C., Sastry, G. and Joshi, B.P., 1981, Manual of soil and water conservation practices in India, Oxford and IBH Publication, 439 pp.*

The 'I' values adopted by Watershed Development Department; Karnataka are given in Table below.

Average Annual Rainfall	I- Values	
	Ten years frequency	Twenty-five years frequency
1. Up to 750 mm.	50 mm per hour	80 mm per hour
2. More than 750 mm.	80 mm per hour	100 mm per hour

These values can be used in place of the Nomograph

Execution of runoff estimation based on Rational method (as elaborated in the LLDD)

- User will input “Maximum length of flow from remote point to the point of concentration (m)” and “Difference in elevation between the remote point and the point of outlet (m)” using Textbox.
- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- Get the Soil texture, Slope, Landform (Black, Red / lateritic) from the Parcel characteristics table for the respective cadastral ID.
- A query will be executed to find current Land use for the selected survey number.
- A query will be executed to find the hourly rainfall for last 24 Hours (rainfall value will be reset at 08:30 am daily).

- A query will be executed on to find the runoff Coefficient (C) using Land use, Soil Texture, Slope as indicated in the Table below.

Land Use	Slope	Texture	Runoff Coefficient
Cultivated Land	1-3	Clay	0.6
Cultivated Land	3-5	Clay	0.6
Cultivated Land	5-10	Clay	0.7
Cultivated Land	10-15	Clay	0.82
Cultivated Land	15-25	Clay	0.82
Cultivated Land	25-33	Clay	0.82
Cultivated Land	33-50	Clay	0.82
Cultivated Land	>50	Clay	0.82
Cultivated Land	<1	Sandy Loam	0.3
Cultivated Land	1-3	Sandy Loam	0.3
Cultivated Land	3-5	Sandy Loam	0.3
Cultivated Land	5-10	Sandy Loam	0.4
Cultivated Land	10-15	Sandy Loam	0.52
Cultivated Land	15-25	Sandy Loam	0.52
Cultivated Land	25-33	Sandy Loam	0.52
Cultivated Land	33-50	Sandy Loam	0.52
Cultivated Land	>50	Sandy Loam	0.52
Pastureland	<1	Clay	0.4
Pastureland	1-3	Clay	0.4
Pastureland	3-5	Clay	0.4
Pastureland	5-10	Clay	0.55
Pastureland	10-15	Clay	0.6
Pastureland	15-25	Clay	0.6
Pastureland	25-33	Clay	0.6
Pastureland	33-50	Clay	0.6
Pastureland	>50	Clay	0.6

Forest Land	<1	Clay	0.4
Forest Land	1-3	Clay	0.4
Forest Land	3-5	Clay	0.4
Forest Land	5-10	Clay	0.5
Forest Land	10-15	Clay	0.6
Forest Land	15-25	Clay	0.6
Forest Land	25-33	Clay	0.6
Forest Land	33-50	Clay	0.6
Forest Land	>50	Clay	0.6
Pastureland	<1	Sandy Loam	0.1
Pastureland	1-3	Sandy Loam	0.1
Pastureland	3-5	Sandy Loam	0.1
Pastureland	5-10	Sandy Loam	0.16
Pastureland	10-15	Sandy Loam	0.22
Pastureland	15-25	Sandy Loam	0.22
Pastureland	25-33	Sandy Loam	0.22
Pastureland	33-50	Sandy Loam	0.22
Pastureland	>50	Sandy Loam	0.22
Forest Land	<1	Sandy Loam	0.1
Forest Land	1-3	Sandy Loam	0.1
Forest Land	3-5	Sandy Loam	0.1
Forest Land	5-10	Sandy Loam	0.25
Forest Land	10-15	Sandy Loam	0.3
Forest Land	15-25	Sandy Loam	0.3
Forest Land	25-33	Sandy Loam	0.3
Forest Land	33-50	Sandy Loam	0.3
Forest Land	>50	Sandy Loam	0.3
Cultivated Land	<1	Clay Loam	0.5
Cultivated Land	1-3	Clay Loam	0.5
Cultivated Land	3-5	Clay Loam	0.5
Cultivated Land	5-10	Clay Loam	0.6
Cultivated Land	10-15	Clay Loam	0.72
Cultivated Land	15-25	Clay Loam	0.72
Cultivated Land	25-33	Clay Loam	0.72
Cultivated Land	33-50	Clay Loam	0.72
Cultivated Land	>50	Clay Loam	0.72
Cultivated Land	<1	Silt Loam	0.5
Cultivated Land	1-3	Silt Loam	0.5
Cultivated Land	3-5	Silt Loam	0.5
Cultivated Land	5-10	Silt Loam	0.6
Cultivated Land	10-15	Silt Loam	0.72
Cultivated Land	15-25	Silt Loam	0.72
Cultivated Land	25-33	Silt Loam	0.72
Cultivated Land	33-50	Silt Loam	0.72
Cultivated Land	>50	Silt Loam	0.72
Pastureland	<1	Clay Loam	0.3
Pastureland	1-3	Clay Loam	0.3

Pastureland	3-5	Clay Loam	0.3
Pastureland	5-10	Clay Loam	0.36
Pastureland	10-15	Clay Loam	0.42
Pastureland	15-25	Clay Loam	0.42
Pastureland	25-33	Clay Loam	0.42
Pastureland	33-50	Clay Loam	0.42
Pastureland	>50	Clay Loam	0.42
Forest Land	<1	Clay Loam	0.3
Forest Land	1-3	Clay Loam	0.3
Forest Land	3-5	Clay Loam	0.3
Forest Land	5-10	Clay Loam	0.35
Forest Land	10-15	Clay Loam	0.5
Forest Land	15-25	Clay Loam	0.5
Forest Land	25-33	Clay Loam	0.5
Forest Land	33-50	Clay Loam	0.5
Forest Land	>50	Clay Loam	0.5
Pastureland	<1	Silt Loam	0.3
Pastureland	1-3	Silt Loam	0.3
Pastureland	3-5	Silt Loam	0.3
Pastureland	5-10	Silt Loam	0.36
Pastureland	10-15	Silt Loam	0.42
Pastureland	15-25	Silt Loam	0.42
Pastureland	25-33	Silt Loam	0.42
Pastureland	33-50	Silt Loam	0.42
Pastureland	>50	Silt Loam	0.42
Forest Land	<1	Silt Loam	0.3
Forest Land	1-3	Silt Loam	0.3
Forest Land	3-5	Silt Loam	0.3
Forest Land	5-10	Silt Loam	0.35
Forest Land	10-15	Silt Loam	0.5
Forest Land	15-25	Silt Loam	0.5
Forest Land	25-33	Silt Loam	0.5
Forest Land	33-50	Silt Loam	0.5
Forest Land	>50	Silt Loam	0.5
Cultivated Land	5-10	Silty Clay	6.7
Cultivated Land	3-5	Sandy Clay	NULL

- If the land use or soil types are different for the area, in such situations, weighted average value of C can be calculated as indicated below:

Cw = A1 CI + A2 C2+ ……An Cn / A

Where,

A is the total area of the watershed,

C1, C2….,Cn are the coefficients of runoff for the different homogeneous areas (equivalent of soil map unit areas) of size A1, A2 ….. An in ha respectively.

- Calculate Time of Concentration (Tc)
    - It is the function of the length of the main channel (L, in m) and fall in elevation from the remotest point to the outlet (H, in m).
    - Alternatively, the Time of concentration (Tc) can also be calculated from the empirical formula

$T_C=0.0195K^{0.77}$

Where K is the square root of L3/H

Where,

L - Maximum length of flow from remote point to the point of concentration (m).

H - Difference in elevation between the remote point and the point of outlet (m)

Tc - Time of concentration (minutes)

Tc (hours) = Tc/60

For Slope= $(\Delta H /L)*100$ in %

$\Delta H=Slope * L/100$

Where,

ΔH is difference in elevation in meters

L is maximum length of the flow in meters

- Calculate Rainfall Intensity (I): Wherever the data on rainfall intensity is not available, it can be calculated as indicated below. Intensity of rainfall (I) for the desired frequency or recurrence interval and for duration equal to time of concentration can be worked out as follows.

$$I = \frac{K_1 T^a}{(b + T_C)^n}$$

Where,

The empirical constants K_1, a, b and n are taken from the table mentioned in (Implementation manual for Sujala – III, Part 2) as per the agro-climatic zone of the selected parcel (at Taluk level).

Tc = Time of concentration (hours)

I = Rainfall Intensity (cm/hr)

I (mm/hr) = I*10

T = Recurrence interval or frequency (years) to be selected from Master Recurrence Interval depending Land use, slope and texture

User will select the below mentioned options of intervention type in the selected parcel to capture the recurrence interval or frequency (in years) to calculate rainfall intensity.

Intervention type	Recurrence interval or frequency (in years)
Bunding / Farmpond / Waste weir	10
Percolation tank / Nalabund/ Checkdam	25

Peak rate of runoff can be estimated by rational method as below.

$$Q = \frac{CIA}{360}$$

Where,

Q - Peak rate of runoff (m^3/s). This value is converted (m3/sec) to mm per day by multiplying by 60*60*24 and then divide the same by 10 to obtain the output in mm

C - Coefficient of runoff [The runoff coefficient C values for different slopes, land use and soil texture are considered as given in the Table earlier. If the land use and soil texture are similar in a watershed area, then only one value of C is valid for the watershed. But, if we get similar land use or soil textures and in such heterogeneous situations, weighted average value of C can be calculated as indicated below:

$Cw = A_1 C_I + A_2 C_2 + \ldots\ldots A_n C_n / A$

Where,

A is the total area of the parcel (Ha),

C_1, C_2….,C_n are the coefficients of runoff for the different homogeneous areas (equivalent of soil map unit areas) of size A_1, A_2 ….. A_n in ha. respectively].

I-Intensity of rainfall (mm/hour) for the duration equal to time of concentration, as in Table 6.7.

- Display the result in a table showing the information such as Survey No, Farmer Name, Area in Hectare, Interval, Runoff (mm).
- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.
- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

Interval	MWS	Area	Peak intensity (mm/hour)	Recurrence interval (years)	Peak rate of runoff (m^3/sec)	Remarks
10 years						
25 years						

There will be no result at soil unit level at present due to the difficulty in estimating the length and height, which can be overcome using DEM later

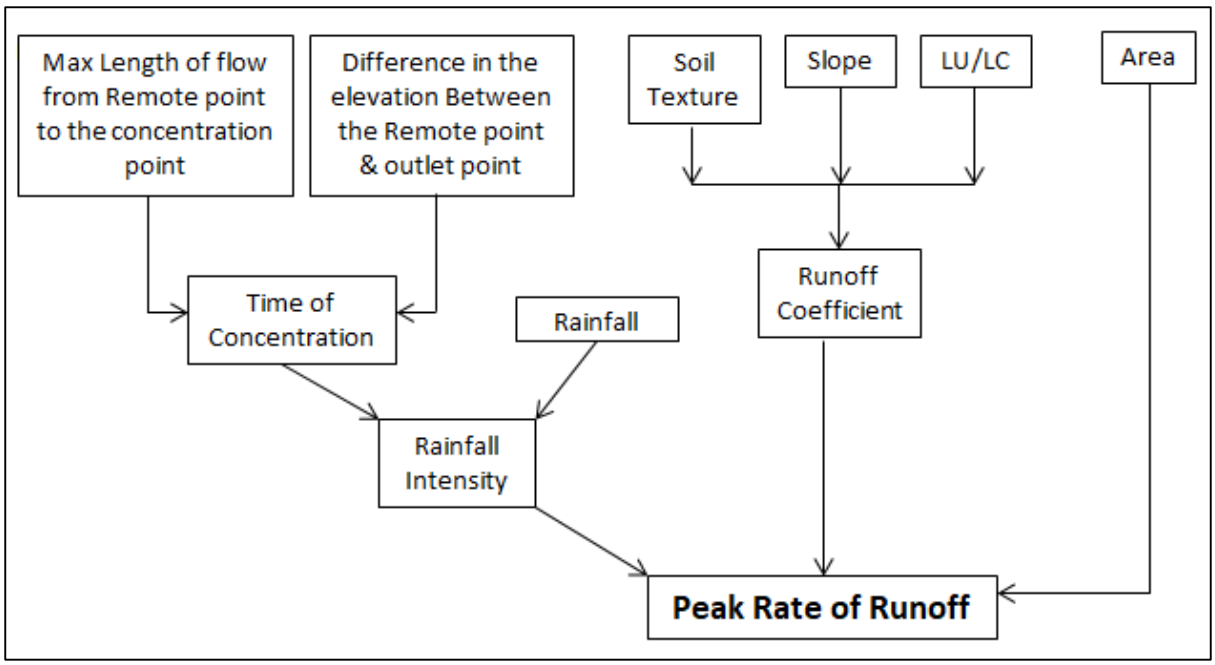

Figure 6.4 Logical Diagram for **Rational Method** as per the LLDD

iii) Infiltration Method (Estimation of Runoff based on Infiltration and precipitation)

This is a new pilot, developed to estimate runoff based on LRI information generated for the watershed areas under Sujala III project. The sequence of activities is described below.

- A query will be executed to find the Cadastral ID on basis of Selected Village, Taluk, District, and Survey Number from CADASTRAL table.
- Get the Soil texture, Slope, Landform (Black, Red / lateritic) from the Parcel characteristics table for the respective cadastral ID.
- A query will be executed to find current Land use for the selected survey number.
    - A query will be executed on Master Infiltration Rate to get constant infiltration rate depending Soil Texture and Land use.
    - Calculate the Rainfall Peak Intensity (mm/hr)
        - Calculate_rainfall = Rainfall at end of storm – Rainfall at start of storm
        - Intensity = Calculated_rainfall / Duration of storm in hrs.
        - If each of the Intensity >= 20 then consider it, else ignore the value
        - Average intensity should be calculated based on average of the interval selected. (Eg: if it is 20-30, the average intensity is 25, if it is 50-60, the average intensity is 55 and so on.

1. Average intensity should be calculated based on average of the interval selected. (Ex: if it is 20-30, the average intensity is 25, if it is 50-60, the average intensity is 55 and so on.

2. If Rainfall has occurred with a storm from 8am to 10am, then consider 8am to 8.30am rainfall and add it to 8.30 to 10am rainfall. This storm will be considered for next day runoff.

3. Depending upon the Soil Texture, Slope and Vegetative Cover, Constant Infiltration rate (mm/hr) is selected from the table mentioned below. User has to select the vegetative cover from the below mentioned percentage (%) and as per the user selection the application will select the infiltration rate according to the Soil texture and Slope (mA, mB, mC, mD, mE and so on) in the selected survey no. (These are values as per the suggestion obtained from Dr. Sathish Kumar, UASR).

For Black soil (i.e. 5 clay bounds)

Soil code	mA	mB	mC	mD	mE
Vegetative cover					
0-20%	9	8.5	8	7.5	7
20-40%	10	9.5	9	8.5	8
40-60%	11	10.5	10	9.5	9
60-80%	12	11.5	11	10.5	10
80-100%	13	12.5	12	11.5	11

For Red/Laterite (i.e. 7 Sand bounds)

Soil code	mA	mB	mC	mD	mE
Vegetative cover					
0-20%	20	19	18	17	16
20-40%	22	21	20	19	18
40-60%	24	23	22	21	20
60-80%	26	25	24	23	22
80-100%	28	27	26	25	24

4. If Slope and Soil Texture are not available, Infiltration rate is considered as 8 for clay bound and 13 for red and lateritic soils.

5. If the selected survey number has different slopes or soil type, then Weighted Average of Infiltration Rate will be considered for the further calculations.

i.e.

Weighted average of Infiltration rate (IR_W) = ($IR_1A_1+IR_2A_2+\ldots\ldots IR_nA_n$) / ($A_1+A_2+\ldots A_n$)

Where,

IR_1, IR_2…., IR_n are the Infiltration rates for the different slopes or soil type areas of size A_1, A_2 ….. A_n respectively.

6. **Net instantaneous runoff** is estimated by subtracting Infiltration rate due to Slope and Vegetation (mm/hr) from Average Rainfall Intensity (mm/hr).

Net Instantaneous Runoff Rate = (Average Rainfall Intensity) – (Infiltration rate)

7. By multiplying Net Instantaneous Runoff Rate with Possible Duration of Rainfall, Impact Factor and Number of Possible Events, Design Runoff Depth (mm) (Rd) is estimated (potential runoff).

Design Runoff Depth = (Net Instantaneous Runoff) * (Impact Factor)*(Number of Events)

Note: Design Runoff Depth is now considered as Potential Runoff.

8. Impact factor is considered as 1.

9. An input is asked to the User to enter the length of the bunding structure (m) if it is present in the selected survey no. or from the conservation maps generated for the area.

10. Anticipated Water Spread Area (m^2) is calculated as 1/2*10m*0.3m=0.75

11. Design Runoff Retained (Rr) (mm) is calculated by multiplying Minimum Length of the Bund (m) and Anticipated Water Spread Area (m^2).

Design Runoff Retained = (min length of the bund) * (Anticipated Water Spread Area) / 10

12. If Design Runoff Depth is greater than Design Runoff Retained, Design Runoff Excess (RE) (mm) is calculated as "Design Runoff Depth – Design Runoff Retained", else it is equal to "0".
If Rd > Rr,
Design Runoff Excess = Design Runoff Depth – Design Runoff Retained
Else,
Design Runoff Excess = 0

13. Number of possible events is taken up for the whole day between the considered range i.e. if the Rainfall intensity value falls in any of the intervals (say 40-50, 50-60, 60-70 and so on up to 190-200), those no. of rainfall intensity within that interval need to be counted. For eg: if the Rainfall Intensity is 55mm/hr, 40 mm/hr, 32 mm/hr, 57 mm/hr, 89 mm/hr, 59 mm/hr and so on, then 55, 57 and 59 fall into 50-60 interval class and the no. of possible events in this class is 3. In 40-50 interval class, no. of possible events is 1 and in 80 to 90 interval class, no. of possible event is 1. 32 will not be considered, as it is less than 40mm. Anything above 200 will be considered in 190-200 interval class.

14. Design runoff excess is termed as Runoff excess after bunding.

15. Total Runoff Excess after Bunding (mm) will be the runoff excess after bunding for the corresponding land parcel area. This will be the final output of total runoff for the selected survey no. in the result table.

- Display the result in a table showing the information such as Survey No, Farmer Name, Area in Hectare, Interval, Runoff (mm).

- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.

Note: Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

Survey number wise Runoff as per Infiltration method

Survey number	Area (Ha/ Acre)	Daily Rainfall (mm)	Potential Runoff (mm)	Runoff Excess (mm)	Potential Runoff Volume (Cu.m)	Runoff Excess Volume (Cu.m)	Remarks

Farmer details will be provided separately in another table
Potential Runoff Volume= Potential Runoff (in mm)* Area in Ha * 10 --- m^3
Runoff Excess Volume = Runoff Excess * Area in Ha * 10 --- m^3

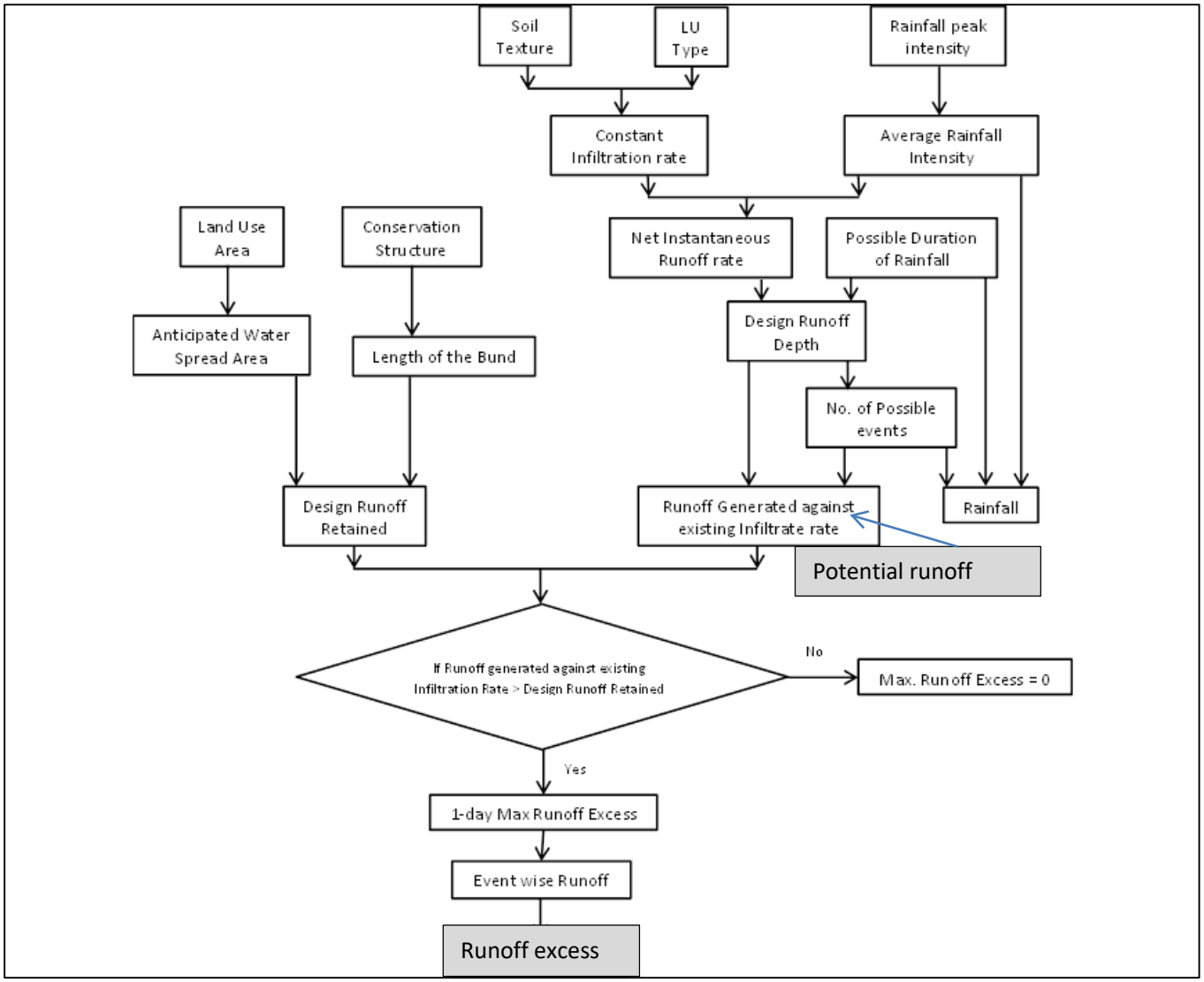

Figure 6.5 Flow Diagram for estimating runoff as per Infiltration Method (to be revised)

Note: The excess runoff is used for the construction of farm ponds and check dams after allowing 30 per cent runoff as environmental flow

Chapter 7

Designing the Size of Farm Ponds and Check Dams based on runoff calculation

7.1 **Farm Ponds**

Farm ponds are manmade ponds constructed for storing rainwater which could be used during scarce season to ensure lifesaving irrigation for the uninterrupted physiological activities of the crops. Farm ponds are constructed by excavating the soil, by depositing the soil on the bunds. These ponds may be lined with impermeable membrane such as HDPE sheet to avoid infiltration of water into soil. However, unlined ponds are more suitable for groundwater recharge.

The excavated ponds are generally made in relatively level regions across waterways, small gullies or to one side of them. They are preferably located in areas with impervious substratum. These ponds should be as deep as possible within the limitations of workability and pumping conditions

Source for this module:

Institution of Agricultural Technologists (IATA), 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru-560 052.

Table 7.1 Step-by-step processes for designing the farm pond

Step	Description	Remark
1	Get the land parcel number and location information	
2	Get the catchment area if catchment area is more than land parcel area	
3	Estimate total quantity of potential runoff	As per the SCS and Infiltration method
4	Based on the runoff available decide farm pond size to capture the runoff quantity	
5	Estimate cost using standard rates (cubic meter basis)	
6	Display results: farm pond size and cost estimate	

Note: For black or red soil, the maximum size of farm pond allowed for one Ha area is 250 cum. This is arrived by considering 2 lifesaving or supplementary irrigations of 50 mm each (flood irrigation) is to be provided, which is equal to 1000 cum. Since this much runoff is not likely to be available and it is possible to provide about 1/4th of the area with 2 irrigations. Accordingly, the size of the farm pond is fixed as 250 cum for one Ha area.

Table 7.2 Calculating cost of Farm Ponds based on Cubic meter rate (Amount in Rupees/cum)

South Zone		North Zone		North Zone (Shimoga & Chithradurga dists.)		North East Zone	
Clayey/ black soil	Loamy /red soil	Clayey/ black soil	Loamy/ red soil	Clayey/ black soil	Loamy /red soil	Clayey/ black soil	Loamy/ red soil
172	**164**	**186**	**179**	**173**	**164**	**183**	**206**
Districts.		**Districts.**		**Districts.**		**Districts.**	
Kodagu		Dharwad		Shimoga		Bellary	
Udupi		Gadag		Chithradurga		Raichur	
South Canara		Haveri				Koppal	
Hassan		Belagavi				Kalburgi	
Chickmagalore		Uttara kannada				Yadgir	
Mysore		Bijapur				Bidar	
Mandya		Bagalakote					
Chamaraja nagara		Davanagere					
Ramanagaram							
Tumkur							
Chickballapur							
Bangalore(u)							
Bangalore®							
Kolar							
1) Without smoothening of segments 2) costing as per WDD schedule of rate- 2018-19							

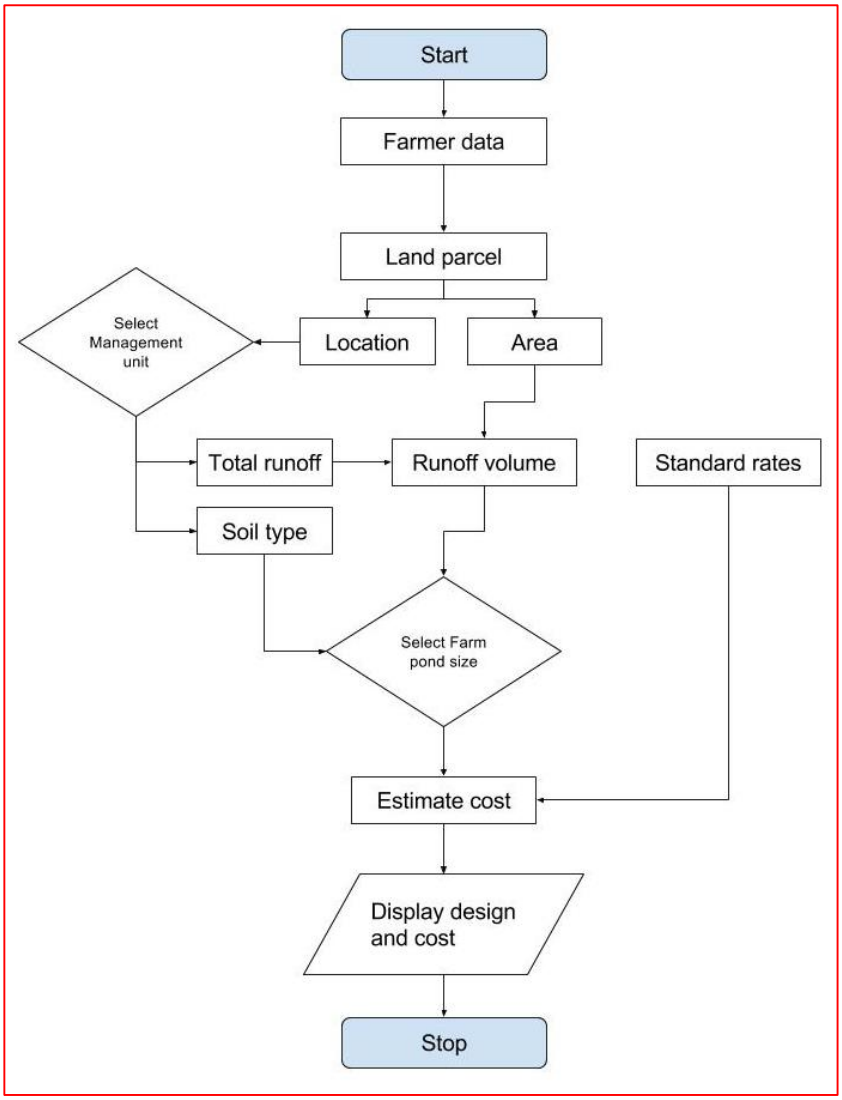

Figure 7.1: Flow diagram for designing farm ponds as per the FRS

Description of the steps involved in the execution of the DSS on Farm Pond as per the LLDD

After successful login, user will click on 'Farm Pond Size' under Decision Support System. A web page for Farm Pond Size DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number. "From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will auto fill the District, Taluk, Village and Survey number values.
- User will select the District, Taluk, Village, Micro Watershed, Survey number, vegetation cover and bund length.

- Execute query on rainfall data to get Peak Intensity Rainfall from the last 10 years.
- Execute Surface Runoff DSS using Infiltration method for the Selected Survey Number considering peak intensity rainfall.

The application decides the farm pond size based on following steps

Slide Slope Consideration:

For Black Soil: 1.5:1

For Red Soil: 1:1

Depth needs to be considered as 3 m.

Top Width = √(Runoff Volume/3) +4.5 for Black soil

Top Width = √(Runoff Volume/3) +3 for Red Soil

Bottom Width = √(Runoff Volume/3) - 4.5 for Black soil

Bottom Width = √(Runoff Volume/3) - 3 for Red Soil

Top Area = Top Width * Top Length

Since its square Top width = Top Length

Bottom Area=Bottom Width*Bottom Length

Since its square Bottom width = bottom Length

Volume = (Top Area + Bottom Area)/2 * Depth

e.g

Depth of Farm Pond : 3 m

70% Surface Runoff : 1500 m3

Soil Type : Black Soil, Slide Slope consider as 1.5:1

Top Width = √(1500/3) +4.5 = 26.8608 (Round off the Top width to = 27 m)

Top Area = Top Width X Top Length = 27 * 27 = 729 m2

Bottom Width = √(1500/3) - 4.5 = 17.8608 (Round off the Bottom width to = 18 m)

Bottom Area = Bottom Width X Bottom Length = 18* 18 = 324 m^2

Volume of Farm Pond = (Top Area + Bottom Area) / 2 * Depth

= (729 + 324)/2) * 3 = 1579.5 m^3

The Farm Pond Size will be = 27 X 27 X 3

- Further, the application will check for the Storage Capacity (m^3) by considering the 70% Runoff for the purpose of harvesting (from DSS 5.2 – Infiltration method)
- Depending on the standard rates of farm pond construction, cost of construction (rupees) is estimated (Table 7.2).

- Total Surface runoff (mm/year) is displayed in the final output table along with the farm pond size and the cost of construction. Display the Farm owner details based on the data fetched for cadastral from Bhoomi data.

- Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

Survey Number	Excess Runoff (Cu.m)	Net Runoff (Cu.m)	Farm Pond Size	Volume of Farm Pond (Cu.m)	Cost of Construction	Action
123	2142.86	1500	27 X 27 X 3	1579.5	271674	Custom

Farmer's Name and details will be from another table
Note: For peak intensity, consider the highest peak event average for the storage capacity of the farm pond.

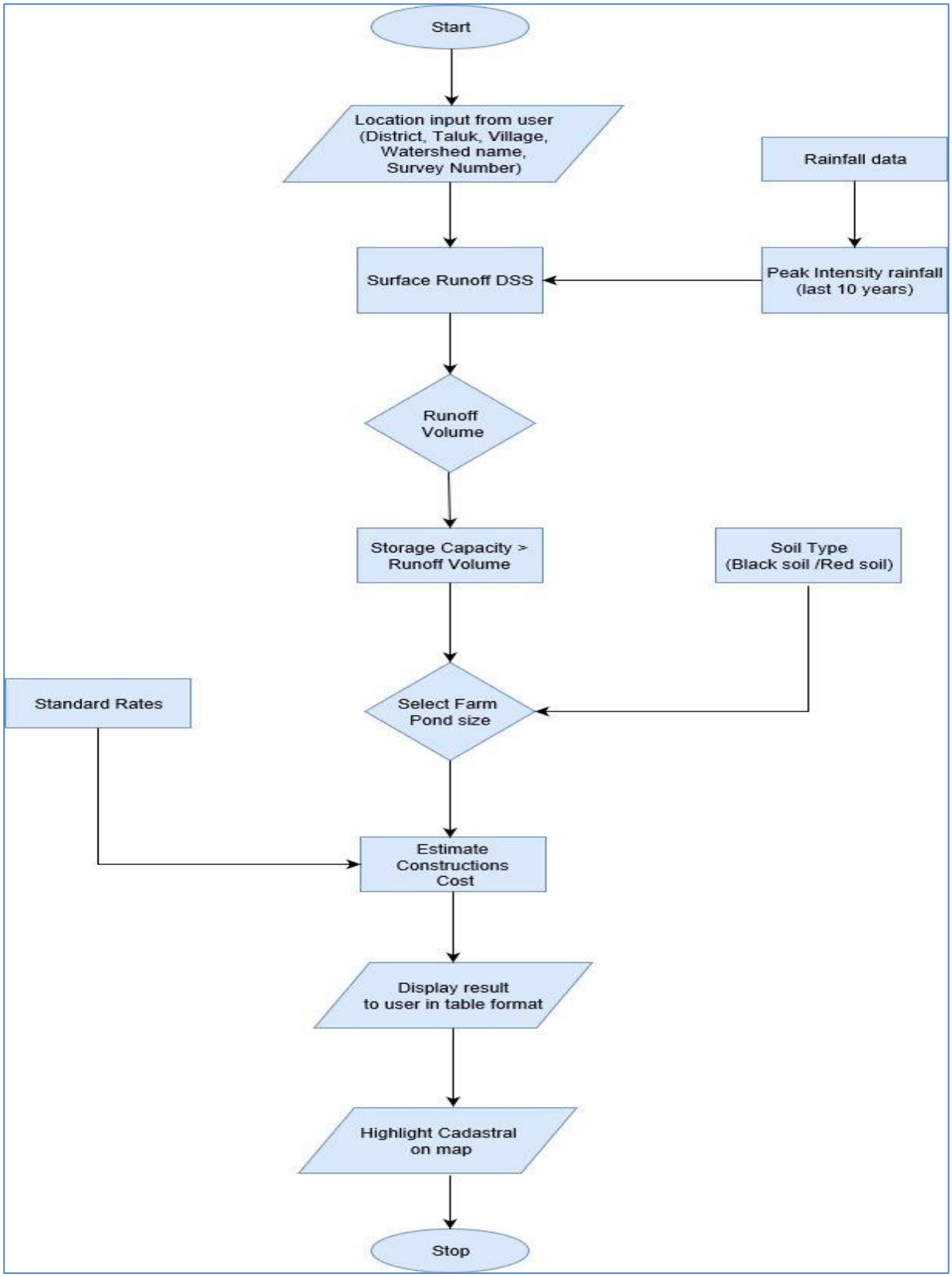

Figure 7.2 Logical Flow Diagram for the development of DSS on Farm Ponds as per the LLDD

7.2 Development of DSS for Check Dam

Drainage line is a natural water course conveying run off from ridge point to the point of concentration or outlet. Drainage line needs to be protected with vegetative measures and stone/boulder checks to reduce the silt load in the runoff to the storage structures. Masonry and Earthen barriers can be put up to create head to harvest run off water for recharge of ground water. Check dam is a stone masonry structure put up across the drainage line with catchment of more 25 to 200 ha for harvesting runoff and to facilitate ground water recharge.

Steps involved in the construction of Check Dam

- Codification of the Drainage network (Stream order No.)
- Demarcating the catchment of each order (first/second etc.) of the Drainage network using LRI Maps.
- Estimate total quantity of potential runoff depth in mm for each stream order.
- Knowing the catchment area (Ha.) of each order and potential depth of runoff (mm.), quantity of available total runoff (Q) is arrived at by using the formula and consolidated in Tables 7.3a and 7.4. Q (Cum.) = catchment area of the stream order in question (Ha.) *10 *Potential runoff depth (mm.).

Note: Since the delineation and estimation of runoff at first and second stream order level is not possible at present, the potential runoff to be obtained for the whole MWS is to be taken into consideration for deciding the number of check dams under this DSS.

Accordingly, **the steps to be followed** for deciding the number of Check dams that can be planned in a watershed area are as indicated below

After successful login, user will click on ‘Check Dam’ under Decision Support System. A web page for DSS will be displayed to the user.

- The web page will have the drop down for selecting District, Taluk, Village, Watershed name, etc.
- User will select the District, Taluk, Village, Micro Watershed.
- By establishing a link with DSS based on Infiltration method (to estimate Surface Runoff), Calculate Excess runoff (Q) for the micro watershed.

  Q (Cum.) = catchment area of the stream order in question (Ha.) *10 *Potential runoff depth (mm.).

Note: The retention of runoff by conservation structures are already captured in the infiltration method

2. Farm ponds in the catchment: Storage capacity of all the ponds in the Catchment to be arrived. In the infiltration method, there is no provision to capture this storage, may be provision can be made to add this as an input data

3. Estimate the Net runoff available for harvesting by **deducting the quantity of runoff** likely to be captured/retained in the **proposed and existing conservation structures** and

farm ponds (about 50 % of the runoff, if no data is available) from the Total quantity of available runoff.

4. Deduct **30 per cent o**f the Runoff from the Total runoff towards Environmental flow. (Out of estimated runoff average **70 per cent** of water to be targeted for harvesting within watershed boundary and rest amount to be allowed to flow at downstream location such that it will not significantly affect riverine ecosystem)

5. If net runoff (available for storage) is sufficient (Minimum of **850 Cum)** Check dam can be proposed at the point where quantity of runoff is sufficient for Check dam. It can be in 1st, 2nd, or 3rd order stream or if the runoff is not enough at any point in the Micro watershed, then there is no need to construct a Check dam & runoff can be allowed to run into the stream. (Option should be given to enter the Storage Capacity of the Check Dam anything greater than 850),

Number of Check Dams = Net Runoff / Minimum Storage

[Table 7.3 (b)] (Round off to next lowest number).

6 Based on the quantity of Net runoff available, number and storage capacity of the Check Dam, Cost of the structure is decided based on the cost for per Cum (Approximately, South Zone Rs 502/-, North Zone Rs 464/- , North East Zone Rs.601/-) as per the prevailing rates in the districts (Tables 7.5 and 7.6).

7 Type of the check dam is decided based on the shape of the nala banks as per ground truth or with the help of DEM data wherever available & availability of the stones nearby.

8 Design of Check dam [Impounding height(h), Spillage/depth of flow over the crest(d) and free board depth(f)], type of the check dam and its components are decided based on the spot selected after Field survey/verification (Tables 7.5 and 7.6).

In order to reduce silt load to Check dams, vegetative or dry boulder checks are provided at a vertical interval of 1 to 1.5m. with a crest height of o.6 to 1.25 m. depending on the depth of the drainage line. If head of the gully or starting point of the drainage line is more than 1 m depth, chute spill way or Boulder flume with Dry boulders are provided. In Black soil area and hilly zone, Gabion checks are preferred. Designing of dimension of these checks are based on the Total Station Survey or survey using Dumpy Level.

Display of check dam at MWS level

Water-shed code/name	Area ha (acre)	Total run-off excess (m^3)	Environmental flow (m^3) (30% of runoff excess)	Net runoff (m^3) (70% excess)	10 % of Net runoff (m^3)	No. of Check dams proposed	Runoff retained by Check dam (m^3)	Balance runoff (m^3)	Cost of construction (Rs.)

Table 7.3 (a) Estimation of Runoff from **Micro watershed** area for deciding the number of Check Dams

Runoff from Micro watershed code.no.:……, Taluk: ,Dist.: for design of Check Dam														
Sl. No (1)	Micro watershed code no. (2)	Average annual rain fall(mm) (3)	Balance runoff from the upper/adjoining linked mws (cum) (4)	Stream order No.3/4/5/6 (runoff can be estimated for each stream order if possible and aggregated to get the total runoff from the watershed area or runoff can be estimated for the watershed as a whole if order level data is not available for the watershed area).										
				Catchment area(ha) (5)	Potential runoff (mm./ha (6)	Total runoff(cum) (col.5 x 6) (7)	Environmental flow (cum) [30% of col.7] (8)	Balance runoff (cum) [col.7 - col.8] (9)	Runoff retained in the proposed conservation & storage structures (cum.) (10)	Net runoff (cum) available for storage [(col.7 + col.4) - col.10]	Check dam required (runoff > 850cum) or not (<850cum)	Number of check dams proposed	Runoff retained in the proposed check dams(cum)	Excess runoff (cum) (col.11 - col.14)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table 7.3 (b) Estimation of Runoff from micro **watershed** area for deciding the number of Check Dams

Sl. No	Micro watershed code no. A	Catchment area (ha) B	Total runoff Excess from the MWS (cum) C	Total environmental flow (Cum) D	Number of check dams proposed E	Runoff Volume retained per check Dam (Cum) F = **850* X E**	Balance runoff from the MWS (cum) G= (C-F)	Total Cost of Construction (Rs.) H = Cost X E	Remarks

* (minimum whatever selected input form)

Table 7.4 Estimation of Runoff from **Sub watershed** area for deciding the number of Check Dams

Sl. No	Micro watershed code no.	Catchment area (ha)	Total runoff from the MWS (cum)	Total environmental flow (Cum)	Number of check dams proposed	Stream order number.	Total runoff retained in the proposed conservation & storage structures (Cum.)	Runoff retained in CDs (Cum)	Balance runoff from the MWS (cum)	Remarks

Table: 7.5 Criteria for deciding crest height and cost of check dam.						
Sl.No	Storage capacity (cum.)	Cost (Rs.)	Check dam-apron type	Catchment area (ha)	Gully depth (m.)	Crest height (h) (m)
1	859	342328	Sloping Apron Type	25	2.4	1.25
2	859	302989	Solid Apron type	25	2.3	1.25
3	703	227782	Stilling basin type	25	2.5	1.25
4	859	397132	Sloping Apron Type	50	2.6	1.25
5	859	336306	Solid Apron type	50	2.4	1.25
	703	264233	Stilling basin type	50	2.7	1.25
6	859	426703	Sloping Apron Type	75	2.7	1.25
7	859	378050	Solid Apron type	75	2.5	1.25
8	703	293227	Stilling basin type	75	2.8	1.25
9	859	464677	Sloping Apron Type	100	2.8	1.25
10	859	417877	Solid Apron type	100	2.6	1.25
11	703	316668	Stilling basin type	100	2.9	1.25
12	859	497115	Sloping Apron Type	125	2.9	1.25
13	859	460812	Solid Apron type	125	2.7	1.25
14	703	341135	Stilling basin type	125	2.9	1.25
15	859	538132	Sloping Apron Type	150	3	1.25
16	859	507143	Solid Apron type	150	2.8	1.25
17	703	373284	Stilling basin type	150	3	1.25
18	859	580771	Sloping Apron Type	175	3.1	1.25
19	859	507143	Solid Apron type	175	2.8	1.25
20	703	399675	Stilling basin type	175	3.1	1.25
21	859	580771	Sloping Apron Type	200	3.2	1.25
22	859	562328	Solid Apron type	200	2.9	1.25
23	703	434107	Stilling basin type	200	3.2	1.25
24	1088	449349	Sloping Apron Type	25	2.6	1.50
25	1088	399529	Solid Apron type	25	2.6	1.50
26	863	264090	Stilling basin type	25	2.7	1.50
27	1088	513982	Sloping Apron Type	50	2.8	1.50
28	1088	440895	Solid Apron type	50	2.7	1.50
29	863	287183	Stilling basin type	50	2.8	1.50
30	1088	548469	Sloping Apron Type	75	2.9	1.50
31	1088	462223	Solid Apron type	75	2.8	1.50
32	863	336222	Stilling basin type	75	3	1.50
33	1088	592776	Sloping Apron Type	100	3	1.50
34	1088	520044	Solid Apron type	100	2.9	1.50
35	863	362125	Stilling basin type	100	3.1	1.50
36	1088	629983	Sloping Apron Type	125	3.1	1.50

37	1088	520044	Solid Apron type	125	2.9	1.50
38	863	389018	Stilling basin type	125	3.2	1.50
39	1088	629983	Sloping Apron Type	150	3.1	1.50
40	1088	582070	Solid Apron type	150	3	1.50
41	863	389018	Stilling basin type	150	3.2	1.50
42	1088	668668	Sloping Apron Type	175	3.1	1.50
43	1088	642906	Solid Apron type	175	3.1	1.50
44	863	416646	Stilling basin type	175	3.3	1.50
45	1088	708560	Sloping Apron Type	200	3.2	1.50
46	1088	710739	Solid Apron type	200	3.2	1.50
47	863	445390	Stilling basin type	200	3.4	1.50
48	1334	575633	Sloping Apron Type	25	2.9	1.75
49	1334	431994	Solid Apron type	25	2.7	1.75
50	1028	378216	Stilling basin type	25	3	1.75
51	1334	613285	Sloping Apron Type	50	3	1.75
52	1334	543010	Solid Apron type	50	2.9	1.75
53	1028	390019	Stilling basin type	50	3.1	1.75
54	1334	690268	Sloping Apron Type	75	3.1	1.75
55	1334	603543	Solid Apron type	75	3	1.75
56	1028	419108	Stilling basin type	75	3.2	1.75
57	1334	690268	Sloping Apron Type	100	3.2	1.75
58	1334	603543	Solid Apron type	100	3	1.75
59	1028	480240	Stilling basin type	100	3.4	1.75
60	1334	739550	Sloping Apron Type	125	3.3	1.75
61	1334	666105	Solid Apron type	125	3.1	1.75
62	1028	480240	Stilling basin type	125	3.4	1.75
63	1334	773298	Sloping Apron Type	150	3.4	1.75
64	1334	732756	Solid Apron type	150	3.2	1.75
65	1028	512335	Stilling basin type	150	3.5	1.75
66	1334	817042	Sloping Apron Type	175	3.5	1.75
67	1334	732756	Solid Apron type	175	3.2	1.75
68	1028	545416	Stilling basin type	175	3.6	1.75
69	1334	871650	Sloping Apron Type	200	3.6	1.75
70	1334	804059	Solid Apron type	200	3.4	1.75
71	1028	579519	Stilling basin type	200	3.7	1.75
72	1600	723204	Sloping Apron Type	25	3.1	2.0
73	1600	568390	Solid Apron type	25	3	2.0
74	1200	407702	Stilling basin type	25	3.1	2.0
75	1600	764852	Sloping Apron Type	50	3.2	2.0
76	1600	692788	Solid Apron type	50	3.2	2.0
77	1200	472013	Stilling basin type	50	3.3	2.0
78	1600	807814	Sloping Apron Type	75	3.3	2.0

79	1600	692788	Solid Apron type	75	3.2	2.0
80	1200	495774	Stilling basin type	75	3.4	2.0
81	1600	842156	Sloping Apron Type	100	3.4	2.0
82	1600	761472	Solid Apron type	100	3.3	2.0
83	1200	530478	Stilling basin type	100	3.5	2.0
84	1600	898578	Sloping Apron Type	125	3.5	2.0
85	1600	834611	Solid Apron type	125	3.4	2.0
86	1200	566242	Stilling basin type	125	3.6	2.0
87	1600	946057	Sloping Apron Type	150	3.6	2.0
88	1600	834611	Solid Apron type	150	3.4	2.0
89	1200	603119	Stilling basin type	150	3.7	2.0
90	1600	946057	Sloping Apron Type	175	3.6	2.0
91	1600	922633	Solid Apron type	175	3.5	2.0
92	1200	640979	Stilling basin type	175	3.8	2.0
93	1600	1085830	Sloping Apron Type	200	3.7	2.0
94	1600	1005462	Solid Apron type	200	3.4	2.0
95	1200	679939	Stilling basin type	200	3.9	2.0
	NOTE: 1. Gully bed width considered is 5m. 2. Gully bed slope considered is 1% 3. Cost is as per WDD SOR: 2018-19 - SUTH ZONE(PWP&ILWTD)					

Table:7.6 Type of check dam:

SHAPE OF NALA BANKS	STONE AVAILABILITY	NALA BED CONDITION	TYPE OF CHECK DAM
'V' Shape Nala bank with side slope milder than 1:1	Available at less than 5km distance	Hard strata at a depth less than 1.0m	Sloping Apron type.
'V' Shape Nala bank with side slope milder than 1:1	Available at more than 5km distance	Clayey/ lateritic soil	Solid Apron Type
'U' Shape Nala bank with side slope steeper than 1:1		Hard strata at a depth more than1.0m	Stilling Basin Type

Location of Check Dams in MWS/SWS area

Identifying proper site for a check dam or Gokatte or any other harvesting structure in a watershed area needs information on the length, width and depth of the stream/drainage line and nature of the substratum apart from the amount of runoff available for harvest in the selected location. At present this information is not available from the LRI/Hydrology data collected from the watersheds. An attempt can be made to collect the above information in the areas already covered by LRI and included as a part of LRI for the new areas in future.

Once this information is available, tentative locations for check dams can be identified, which can be verified later in the field. Alternatively, attempts can be made to identify suitable locations by using higher resolution imagery available from the project and DEM wherever available. Once the protocol for the use of the imagery/DEM is established for locating Check dams, the same can be integrated in the DSS already developed.

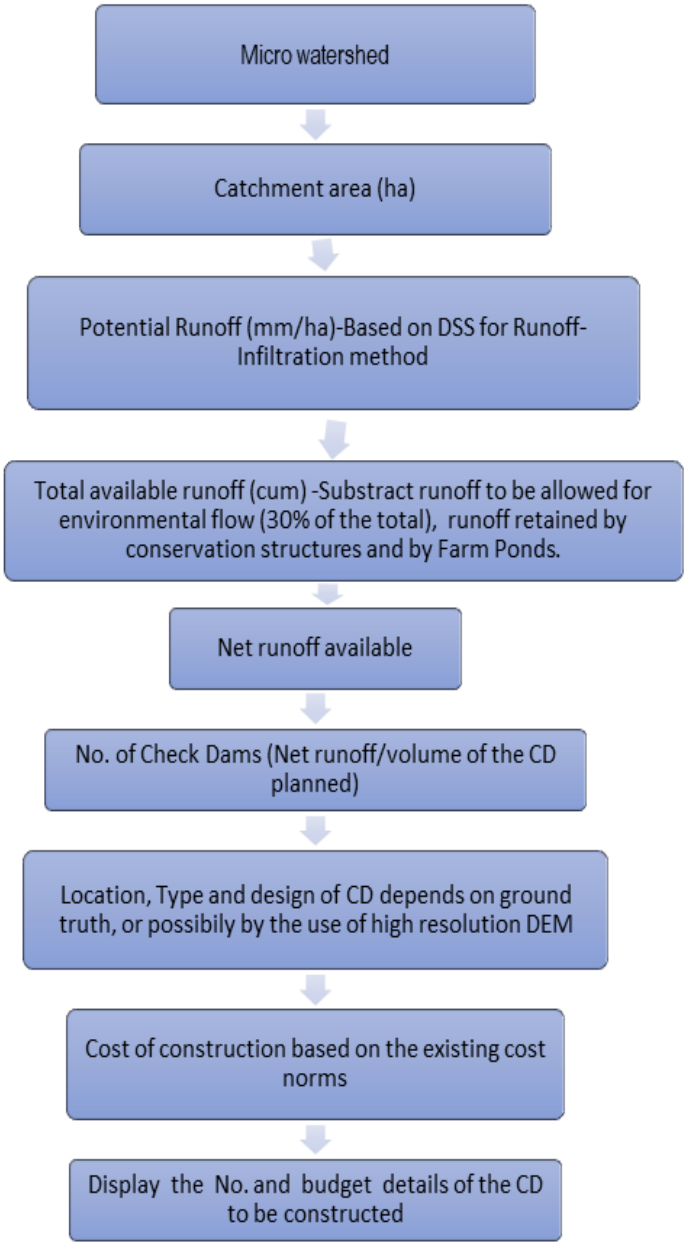

Figure 7.3 Flow diagram for deciding runoff storage structure- check dam as per the FRS

Chapter 8

Estimation of Crop Water requirement

The amount of water that needs to be supplied to the cropped field is defined as crop water requirement or Crop Evapotranspiration (ETc). Crop water requirement is estimated using FAO 56 method. The common approach to calculate ETc is to estimate a reference crop Evapotranspiration (ETo) using weather variables from nearby weather station and multiplying it by an appropriate crop coefficient (Kc). Inputs required for estimating the crop water requirement is mentioned in Table 8.1. Steps for estimating the crop water requirement given in Table 8.2.

Sources for the module:

1. KK Garg, SP Wani, MD Patil: 2016, Simple and farmer-friendly decision support system for enhancing water use efficiency in agriculture: tool development, testing and validation Current Science
2. Allen, R.G., Pereira, L.S., Smith, M., Raes, D. and Wright, J.L., FAO-56 dual crop coefficient method for estimating evaporation from soil and application extensions. *J. Irri. Drain. Eng.*, 2005, **131**, 2-13.
3. Allen, R.G., Pereira, L.S., Raes, D. &Smith, M., Crop evapo-transpiration - guidelines for computing crop water requirements – FAO irrigation & drainage paper 56. FAO - Food and Agriculture Organization of the United Nations, Rome, 1998.
4. Institution of Agricultural Technologists (IATA), 2006, Technical Manual for Integrated Watershed Development, (Sponsored by Watershed Development Department, Government of Karnataka), Institution of Agricultural Technologists, Queen's Road, Bengaluru-560 052.

Table 8.1: Inputs required for estimating Crop Water requirement

Inputs	Input parameter	Master table	Note
Location information	Geo-coordinates, land area	Micro-watersheds, management units, parcel numbers,	
Weather	Maximum, Minimum Temperature, Relative humidity, solar radiation or Sunshine Hours, wind speed, etc.	Estimate Potential evapotranspiration at daily scale	ETo will be estimated using weather parameters
Crop management details	Crop grown, date of sowing, crop duration	Farmers data, FAO data on crop duration	Length of crop growth stages to be prepared for each crop separately from package of practices publication
Crop growth parameters	Crop coefficient and root growth function at	FAO, NBSS&LUP, NWDA data on	Kc values to be compiled for different crops and for root

	different stages	crop coefficients; Literature from root growth	growth characteristics like very shallow, shallow, medium, deep and very deep

Table 8.2: Steps involved in the estimation of Crop Water requirements

S.No	Description of the steps involved
1	Define land use class/ cropping system and its management details- Input from users-survey number, crop, date of sowing etc
2	Estimate day after sowing
3	Estimate crop coefficient based on days after sowing and crop growth parameters
4	Estimate potential evapotranspiration requirement using measured weather parameters on daily time scale
5	Estimate crop water requirement using crop coefficient (Table 8.3; Figure 8.1) and potential evapotranspiration (Multiply crop coefficient with PET)
6	Display crop-wise water requirement **at parcel level**. (Aggregate crop water requirement at soil unit, MWS and SWS levels based on the crop cultivated)
7	Display crop-wise water requirement to the farmer/other stakeholders

NOTE: Only parcel level output is possible due to the changes in the land use, which varies from parcel to parcel in the watershed area.

Table 8.3 Crop coefficient (Kc) values compiled for major crops (FAO, 1998)

	Crop	Initial stage Kc	Midseason Kc	End season Kc	Remarks
All Small Vegetables		0.7	1.05	0.95	
1	Cabbage		1.05	0.95	
2	Cauliflower		1.05	0.95	
3	Carrots		1.05	0.95	
4	Lettuce		1.00	0.95	
5	Garlic		1.00	0.70	
6	Onions		1.05	0.75	
7	Radish		0.90	0.85	
8	Spinach		1.00	0.95	
9	Broccoli		1.05	0.95	
Vegetables	All Solanaceous crops	0.6	1.15	0.80	
1	Tomato		1.15	0.70-0.90	
2	Egg Plant		1.05	0.90	
3	Capsicum (bell)		1.05	0.90	
Vegetables	All Cucumber family crops	0.5	1.00	0.80	

1	Cucumber	0.6	1.00	0.75	
2	Pumpkin		1.00	0.80	
3	Watermelon	0.4	1.00	0.75	
4	Sweet Melons		1.05	0.75	
5					
Tuber crops	All tuber crops	0.5	1.10	0.95	
1	Cassava	0.3	0.80	0.30	
2	Potato		1.15	0.75	
3	Sweet Potato		1.15	0.65	
4	Turnip		1.15	0.95	
Legumes	All Legumes	0.4	1.15	0.55	
1	Green Gram & Cowpeas		1.05	0.60 (Harvested fresh)	
2	Green Gram & Cowpeas		1.05	0.35 (Harvested dry)	
3	Groundnut		1.15	0.60	
4	Chickpea		1.00	0.35	
5	Soybeans		1.15	0.50	
6	Beans (green)	0.5	1.05	0.90	
Fibre Crops		0.35			
	Cotton		1.15-1.20	0 0.70-0.50	
Oilseeds	All oilseeds	0.35	1.15	0.35	
1	Castor		1.15	0.55	
2	Rapeseed		1.0-1.15	0.35	
3	Safflower		1.0-1.15	0.25	
4	Sesame		1.10	0.25	
5	Sunflower		1.0-1.15	0.35	
Cereals	All cereal crops	0.3	1.15	0.4	
1	Maize		1.20	0.60	
2	Sorghum-grain		1.00-1.10	0.55	
3	Rice	1.05	1.20	0.90-0.60	
4	Millet		1.00	0.30	
5	Bajra				
Sugarcane		0.40	1.25	0.75	
Banana	1st year 2nd year	0.50 1.00	1.10 1.20	1.00 1.10	
Grapes– Table or Raisin		0.30	0.85	0.45	
Pineapple	with grass cover	0.50	0.50	0.50	
Citrus	70% canopy 50% canopy	0.75 0.80	0.70 0.80	0.75 0.80	

[Single (time-averaged) crop coefficients, Kc, for non-stressed, well-managed crops in sub humid climates (RHmin ≈ 45%, u2 ≈ 2 m/s) for use with the FAO Penman-Monteith ETo.]

Reference: FAO (1998) Crop Evapotranspiration-Guidelines for computing Crop water Requirements, FAO Irrigation and Drainage paper 56.

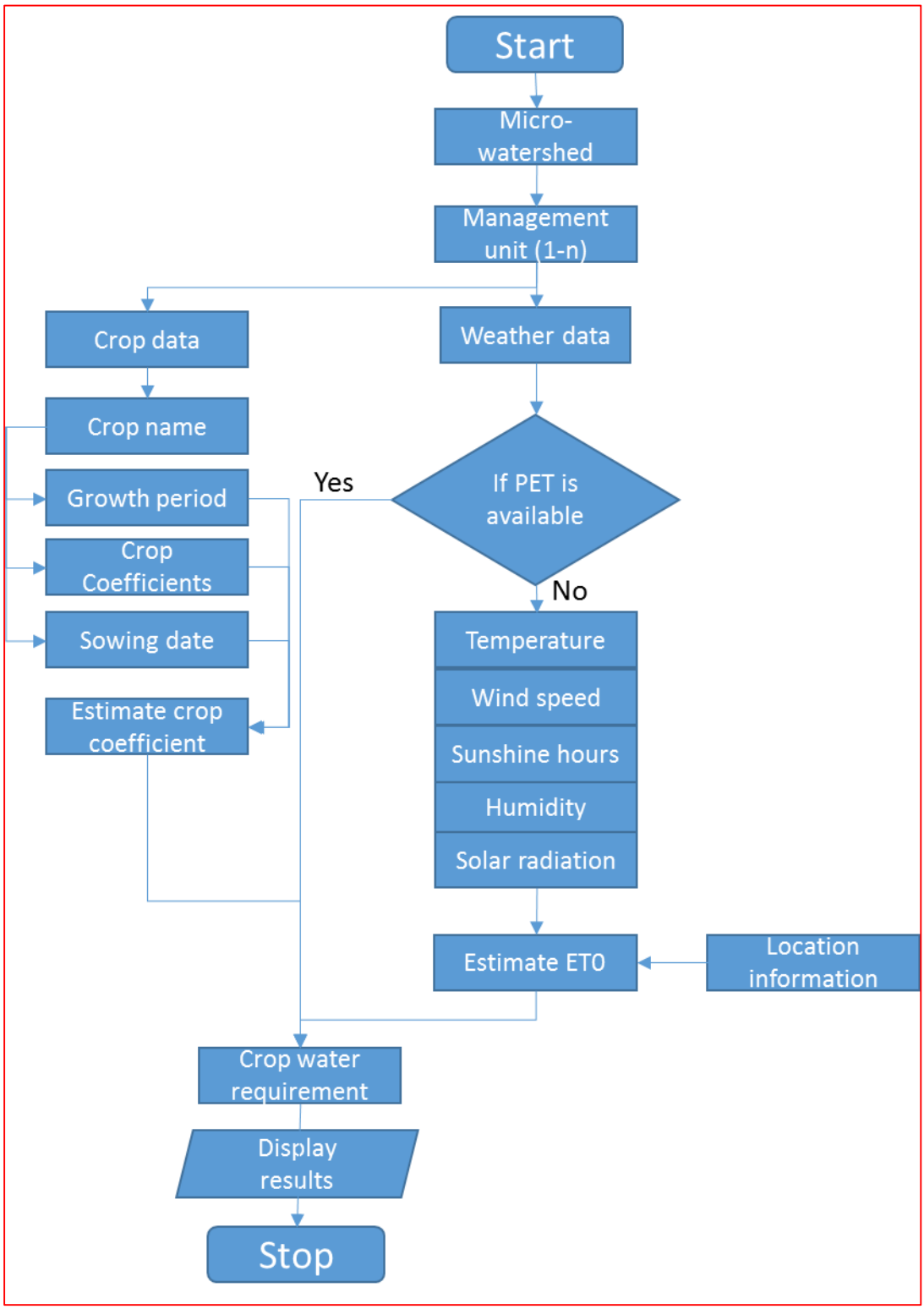

Figure 8.1: Flow diagram for estimating crop water requirements as provided in the FRS

Module Description for the estimation of Crop Water requirement as per the LLDD

After successful login, user will click on 'Crop Water Requirement' under Decision Support System. A web page for Crop Water Requirement DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number, Crop Name, Date of Sowing.**Error! Reference source not found.** From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will autofill the District, Taluk, Village and Survey number values.

- User will select the District, Taluk, Village, Survey number, Crop Name, Date of Sowing

- Execute query on Master Crop table to find out Kc value at initial stage (Kc_{ini}), kc value at mid – season stage ($Kc_{mid\,(tab)}$) , kc value end season stage($Kc_{end(tab)}$) (Table 8.3, Kc value table for major crops), mean maximum plant/crop height for mid s (h), crop duration.(As per POP for each crop and stored in the system)

- Calculate the number of days after Sowing by subtracting date of sowing from current date.

- Execute query on Weather Data table to find out temperature, wind speed, humidity, solar radiation, sunshine hours. Calculate minimum Relative humidity (RHmin), Mean Wind speed (u_2).

- If user selects initial stage time period for a particular crop, then initial crop coefficient (K_{Cini}) value for the same crop will be fetched from crop coefficient table.

- Likewise, if user selects mid stage/end stage for a particular crop, using the middle crop coefficient ($K_{Cmid\,(tab)}$) or *end of the late season growth stage,* end crop coefficient ($K_{Cend\,(tab)}$) value from crop coefficient table, it follows the below mentioned equation.

    - Calculate $K_{c\,mid}$:

$$K_{C\,mid} = K_{C\,mid(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$

Where,

$K_{c\,mid\,(Tab)}$ *- value for* $K_{c\,mid}$ *is taken from given Table,*

u_2 *- Mean value for daily wind speed at 2m height during the midseason growth stage [m* s^{-1}*],*

RH_{min} *- mean value for daily minimum relative humidity during the mid-season growth stage [%],*

h - Mean crop height during the mid-season stage [m],

- Calculate $K_{c\,end}$:

$$K_{C\ end} = K_{C\ end(Tab)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3}$$

Where,

$K_{c\ end\ (Tab)}$ - value for $K_{c\ end}$ taken from Table

u_2 - Mean value for daily wind speed at 2m height during the late-season growth stage [m s^{-1}],

RH_{min} - mean value for daily minimum relative humidity during the late-season growth stage [%]

h - mean plant height during the late season stage [m]

- Mean wind speed (u_2) at 2 m above ground surface will be calculated as:

$$u_2 = u_z \frac{4.87}{\ln(67.8z - 5.42)}$$

Where

u_2 – wind speed at 2 m above ground surface [m s-1]

u_Z – measured wind speed at z m above ground surface [ms_{-1}]

z – height of measurement above ground surface [m].

- Execute query on climate data table and calculate Net radiation (R_n), mean daily air Temperature (T)
  - Estimate Slope of saturation vapour pressure curve (Δ) using below equation

$$\Delta = \frac{4098\left[0.6108exp\left(\frac{17.27T}{T + 237.3}\right)\right]}{(T + 237.3)^2}$$

Where,

Δ - *slope of saturation vapour pressure curve at air temperature T [kPa °C^{-1}],*

T- Mean daily air temperature [°C],xp[..] - 2.7183 (base of natural logarithm) raised to the power [..]

  - Estimate Soil Heat flux (G), where G for a day or ten days, it is relatively small and so it may be ignored in the calculation. Thus:

G_{day} = 0

- Atmospheric pressure (P):

$$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26}$$

Where,

P - Atmospheric pressure [kPa],

z - Elevation above sea level [m]

- Calculate Psychrometric constant (γ):

$$\gamma = 0.665\text{x}10^{-3}P$$

Where,

γ - Psychrometric constant [kPa °C^{-1}]

P - Atmospheric pressure [kPa],

- *e°(T_{min}) and e°(T_{max}) are calculated as follows:*

$$e^0(T_{min}) = 0.6108exp\left[\frac{17.27T_{min}}{T_{min}+237.3}\right]$$

$$e^0(T_{max}) = 0.6108exp\left[\frac{17.27T_{max}}{T_{max}+237.3}\right]$$

Where,

$e°(T_{min})$ – Minimum saturation vapour pressure at the air temperature T_{min} [kPa],

T_{min} – Minimum air temperature [°C],

$e°(T_{max})$ – Maximum saturation vapour pressure at the air temperature T_{min} [kPa],

T_{max} – Maximum air temperature [°C],

exp[..] - 2.7183 (base of natural logarithm) raised to the power [..].

- Calculate Mean saturation vapour pressure (e_s):

$$e_s = \frac{e^0(T_{max}) + e^0(T_{min})}{2}$$

Where,

e_s - Mean saturation vapour pressure [kPa],

$e°(T_{min})$ – Minimum saturation vapour pressure at the air temperature T_{min} [kPa],

$e°(T_{max})$ – Maximum saturation vapour pressure at the air temperature T_{min} [kPa]

- Calculate Actual vapour pressure (ea)

$$e_a = \frac{e^o(T_{min})\frac{RH_{max}}{100} + e^o(T_{max})\frac{RH_{min}}{100}}{2}$$

Where,

e_a – Actual vapour pressure [kPa]

e^o (T_{min}) – Saturation vapour pressure at daily minimum temperature [kPa]

e^o (T_{max}) – Saturation vapour pressure at daily maximum temperature [kPa]

RH_{max} – Maximum Relative Humidity [%]

RH_{min} – Minimum Relative Humidity [%]

- Calculate Slope of saturation vapour pressure curve (Δ)

$$\Delta = \frac{4098\left[0.6108exp\left(\frac{17.27T}{T+237.3}\right)\right]}{(T+237.3)^2}$$

Where,

Δ - slope of saturation vapour pressure curve at air temperature T [kPa °C^{-1}],

T - air temperature [°C],

exp[..]- 2.7183 (base of natural logarithm) raised to the power [..].

- **Calculate Potential Evapotranspiration (PET)**

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where,

ET_0 – Reference Evapotranspiration [mm day^{-1}]
R_n – Net radiation at the crop surface [MJ m^{-2} day^{-1}]
G – Soil Heat flux density [MJ m^{-2} day^{-1}]
T – Mean daily air temperature at 2m height [°C]
U_2 – Wind speed at 2m height [m s^{-1}]
e_s – Saturation vapour pressure [k Pa]
e_a – Actual vapour pressure [k Pa]
$(e_s - e_a)$ – Saturation vapour pressure deficit [kPa]
Δ - Slope vapour pressure curve [kPa $°C^{-1}$]
γ - Psychrometric constant [kPa $°C^{-1}$]

- **Calculate Crop Water Requirement** (Crop Evapotranspiration (ET_C)) depending on crop coefficient of selected growth stage ($K_{C\ ini}$, $K_{C\ mid}$ or $K_{C\ end}$)

  $ETc = K_C\ ETo$

Where,

ET_c - Crop evapotranspiration [mm d^{-1}],
K_c - Crop coefficient [$K_{C\ ini}$, $K_{C\ mid}$ or $K_{C\ end}$],
ET_o - Reference crop evapotranspiration [mm d^{-1}].

- Fetch the Geometry from the Cadastral table against the Cadastral_ID.

[Kc values, if available at different stages of growth, can be used wherever computation is not possible]. This to be provided for all the crops cultivated in the state.

- Read the Coordinates of the geometry and create GeoJson polygon. Send GeoJson to Leaflet to display the polygon with Cyan color and overlay it on the map.

- **Display the result in a table showing the information such as**

[Survey No, Farmer Name, Area in Hectare, Crop Name, Crop Stage (days), Water Required mm/day, Water Required in Ltr/day (mm * 10000*area) (A), Available Soil Moisture Content, Balance C =A-B].

Survey No.	Farmer's name	Are in ha (acre)	Crop name	Stage of the crop	Crop water requirement (m3)	Remarks

- Display the Farm owner details based on the data fetched for cadastral from result grid view through web service integration with Bhoomi.

Note: Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

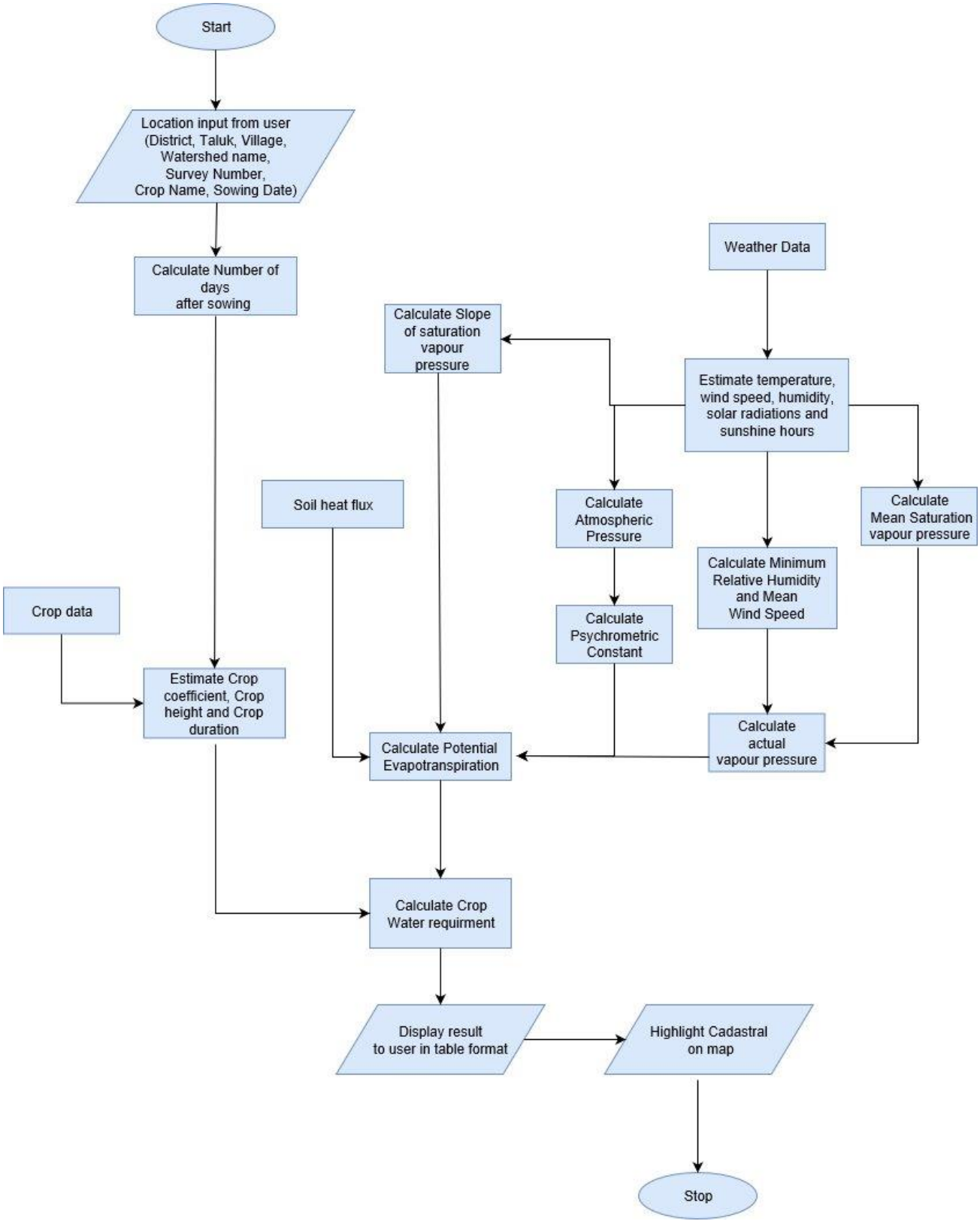

Figure 8.2 Logical Flow Diagram for the estimation of Crop water requirement

Note: When the calculation of PET from weather data is not possible, PET values available from the nearest weather station from KSNMDC can be used

Chapter 9

Estimation of Soil Water (Moisture) Balance

Soil Water (Moisture) is a fundamental hydrological variable affecting physical, chemical and biological properties of soils and in turn impacts the growth and yield of crops. It is influenced by the amount of rainfall, topography, land use, type of soil, substratum and management practices followed in an area. Estimation of the amount of water present in the soil on real time basis will help to take up appropriate contingency measures needed to overcome the stress period wherever possible.

Soil Water (Moisture) balance equation can be defined as:

Change in soil moisture storage = Rainfall + Irrigation - Surface runoff - Evapotranspiration - Deep percolation

References used for this module:

1. Allen, R.G., Pereira, L.S., Smith, M., Raes, D. and Wright, J.L., FAO-56 dual crop coefficient method for estimating evaporation from soil and application extensions. *J. Irri. Drain. Eng.*, 2005, **131**, 2-13.
2. Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., Crop evapo-transpiration - guidelines for computing crop water requirements – FAO irrigation and drainage paper 56. FAO, Rome, 1998.
3. United States Department of Agriculture (USDA), (2012), Soil Survey Manual, Handbook No:18, USDA, USA.
4. Schapp MG, Leij FJ, Van Genuchten M Th, (2001). "ROSETTA: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer function. Journal of Hydrology, 251(3) 163-176.
5. Savva, A. P. & Frenken, K. (2002). Crop Water Requirements and Irrigation Scheduling (Irrigation Manual Module 4) Water Resources Development and Management Officers FAO Sub-Regional Office for East and Southern Africa. 85-89.
6. Arnold JG, Allen PM. (1996). Estimating hydrologic budgets for three Illinois watersheds. Journal of Hydrology 176: 57–77.
7. Garg KK, Wani SP, Patil MD, (2016). Simple and farmer-friendly decision support system for enhancing water use efficiency in agriculture: tool development, testing and validation. Current Science 110(9): 1716-1729.

Table 9.1. Input parameters required for estimation of Soil Water (Moisture) balance

Data base	Required parameter	Master table	Remarks
Soil data base	FC, PWP (Wherever the values are not available the same may be computed from LRI database through PTF models)	Texture, organic carbon, bulk density	(Calculated using *pedo-transfer* function using Texture, OC, BD etc.)
	Soil depth, Infiltration rate (IR values to be provided for	Soil depth, infiltration rate	Soil depth from LRI, Infiltration rate based on

	major soils in the MWS based on LRI)		infiltrometer studies
Weather	Rainfall and weather parameters (max and min temp, relative humidity, wind speed, solar radiation)	Daily rainfall (actual and normal)	Based on weather data, estimate ETo
Crop management details	Date of sowing, crop duration	Farmers data, remote sensing data base,	Crop duration from the POP. Date of sowing will be input by the user
Crop growth parameters	Crop coefficient (Table 8.3) and root growth function at different stages	FAO, NBSS&LUP NWDA data base for crop coefficients	

Table 9.2 Step-by-step process for estimating Soil Water (Moisture) balance

S.No	Steps involved	Data requirement
1	Define soil profile and assign initial boundary condition	Soil data base, WHC (soil series wise), soil depth
2	Define land use class/cropping system and its management details	Crop management details in case of agricultural land
3	Initialize the process for computing the water balance components at daily time scale (Soil moisture, Eta, runoff and deep percolation) at individual field scale	
4	Estimate runoff on daily time scale based on selected model (SCS Method)	Runoff model based on IR and precipitation-not done
5	Calculate balance water by subtracting runoff from rainfall	
6	Distribute balance water into soil by following one-dimensional model	
7	Excess balance water beyond soil depth may be assumed as deep percolation	
8	Estimate crop water requirement on daily time scale	As per the DSS on Crop water requirement
9	Estimate available moisture content in soil up to root zone depth	
10	Estimate soil water storage by subtracting crop water requirement from available moisture content up to root depth	
11	Repeat step 4-11 at daily scale for entire crop growth period	
12	Display water balance component at land parcel scale	

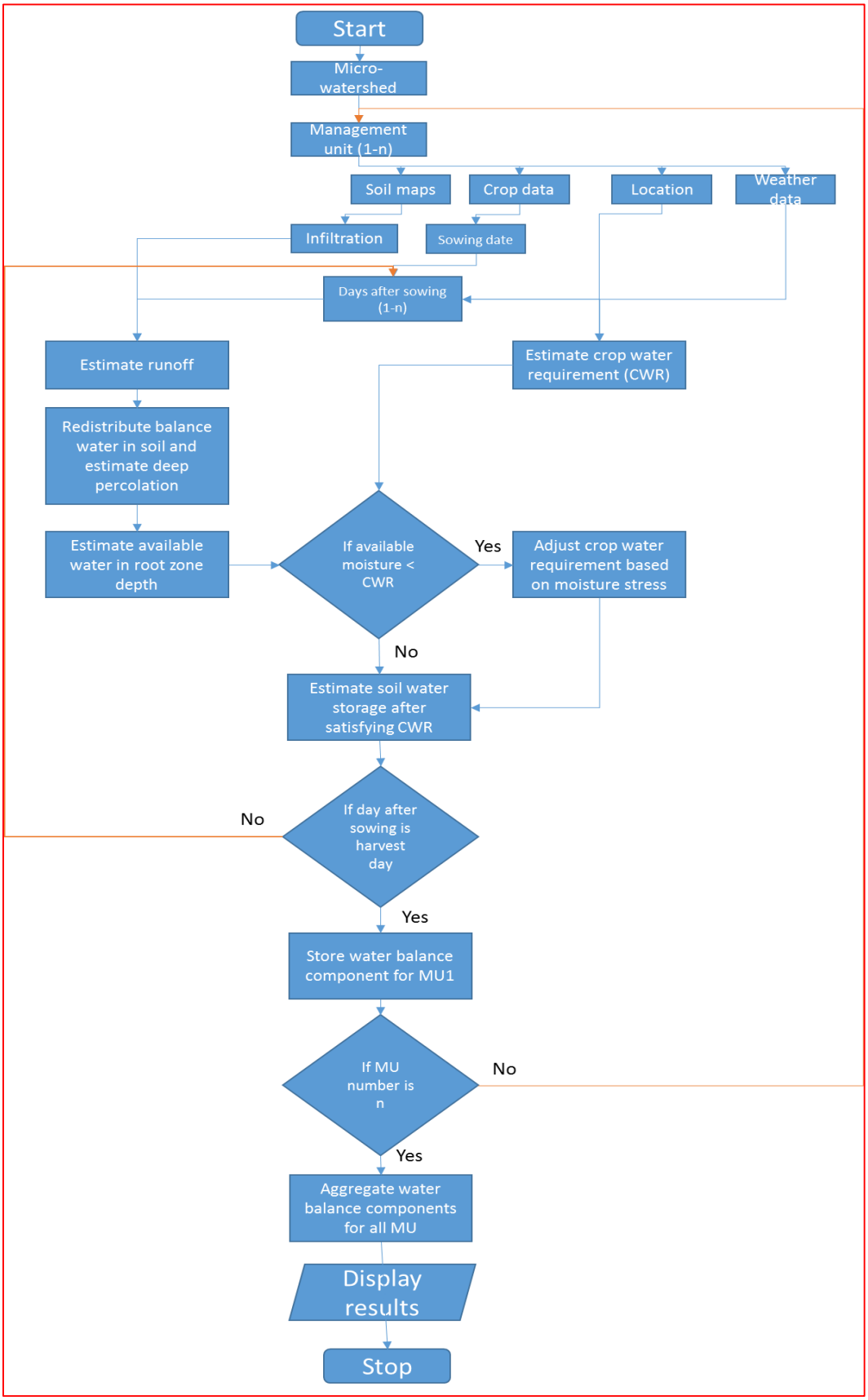

Figure 9.1: Flow chart for estimating Soil Water balance components as given in the FRS document

Execution steps for the estimation of Soil Water (Soil moisture) Balance as per the LLDD

After successful login, user will click on 'Soil Water Balance' under Decision Support System. A web page for Soil Water Balance DSS will be displayed to user.

- The web page will have two options to select cadastral/survey number, "From List" and "From Map". "From List" option allows user to select District, Taluk, Village, Survey Number, Crop Name, Date of Sowing, Last Date of irrigation, irrigation Quantity (mm) and total cropped area. "From Map" option will allow user to select XY coordinate (Lat-Long) on the map (Cadastral) which will autofill the District, Taluk, Village and Survey number values.
- The web page will have the drop down for selecting District, Taluk, Village, Survey Number, Crop Name, Date of Sowing, Last Date of irrigation, irrigation Quantity (mm) and total cropped area. The details of input fields in Web page are as mentioned in section.
- User will select the District, Taluk, Village, Survey number.
- Calculate Surface runoff using DSS for Surface runoff
- Calculate ETc using DSS for Crop water Requirement.
- Subtract runoff from the rainfall obtained for that particular day.

$$\Delta S = P - P_e$$

Where,

ΔS = Water Balance

P= Rainfall

P_e= Surface Runoff

[Note: Calculation of this DSS will be carried from last day of irrigation to the previous date (i.e. if the current date is n, then the Soil water balance is calculated for n-1 day). The crop duration for the selected crop will be taken up in the estimation of Soil water balance as well. The Maximum Root Depth (Zr) will be categorized into 3 groups, namely Shallow root, medium root and deep root. This parameter value will be used to estimate Total Available Water (TAW). The tentative values for Zr as mentioned below are considered.

Shallow root, Zr = 0.1 to 0.3 m
Medium root, Zr = 0.3 to 0.5 m
Deep root, Zr = 0.5 to 0.9 m.

Interpolation of Zr values will be done for the entire crop growing period and the corresponding Zr value at selected crop growth day will be taken up for calculation.]

- To initiate the water balance for the root zone, the initial depletion Dr-1 should be estimated. Calculation of initial depletion (Dr,i-1) is given as:

$$D_{r,i-1} = 1000(\theta_{FC} - \theta_{i-1})Z_r$$

Where,

θ_{FC} – Water content at field capacity [m^3 m^{-3}] (from data)

Z_r – The rooting depth [m] (from data)

θ_{i-1} is the average soil water content for the effective root zone. Following heavy rain or irrigation, the user can assume that the root zone is near field capacity, i.e., $D_{r,i-1} \approx 0$

- Calculate the Readily Available soil Water (RAW):

$$RAW = pTAW$$

Where,

RAW - Readily available soil water in the root zone [mm],

p - Average fraction of Total Available Soil Water (TAW) that can be depleted from the root zone before moisture stress (reduction in ET). We have considered this value as 0.5

- Calculate the Total Available soil Water (TAW):

$$TAW = 1000(\theta_{FC} - \theta_{WP})Z_r$$

Where,

TAW – Total available Soil water in the root zone [mm]

θ_{FC} – Water content at field capacity [m^3 m^{-3}] (from data)

θ_{WP} – Water content at wilting point [m^3 m^{-3}] (from data)

Z_r – The rooting depth [m] (from data)

- Excess balanced water beyond soil depth is assumed as Deep percolation. It is estimated as follows:

$$DP_i = (P_i - P_{e,i}) + I_i - ET_{C,i} - D_{r,i-1} \quad \geq 0$$

Where,

DP - water loss out of the root zone by deep percolation on day i [mm]

P_i - rainfall on day i [mm]

$P_{e,i}$ - runoff from the soil surface on day i [mm]

I_i - net irrigation depth on day i that infiltrates the soil [mm]

$ET_{C,i}$ - crop evapotranspiration on day i [mm]

$D_{r,i-1}$ - water content in the root zone (D_r) at the end of the previous day, i-1 [mm]

- Irrigation is required when Dr,i ≥ RAW. And in this case message will be displayed "Irrigation is required" as a label above the result table.

On day 1, $D_{r,\,i-1}$ = RAW

- Irrigation for the crop will be with reference to Package of Practice.
- Add Irrigation (I) value to the Soil Moisture storage (ΔS)
- Subtract the Deep Percolation (DP) from Soil moisture storage (ΔS)
- If RAW is lesser than ETc, adjust crop water requirement ($ET_{C\ adj}$) based on moisture stress. The effects of soil water stress are described by multiplying the Crop coefficient (K_C) by the water stress coefficient (K_S):

$$ET_{C\,adj} = K_S K_C ET_o$$

Where,

$ET_{C\ adj}$ –Adjusted crop water requirement

K_C – Crop Coefficient

K_S – Water stress coefficient

ET_o – Potential evapotranspiration

- For Dr > RAW, Ks is given by:

$$K_S = \frac{TAW - D_r}{TAW - RAW} = \frac{TAW - D_r}{(1-p)TAW}$$

Where,

K_S - Water stress coefficient

D_r - root zone depletion [mm],

TAW - total available soil water in the root zone [mm],

RAW - Readily available soil water in the root zone [mm]

p - Fraction of TAW that a crop can extract from the root zone without suffering water stress.

- When the root zone depletion (Dr) is smaller than RAW, Ks = 1
- Fraction of TAW, P will be taken from the data provided.

Subtract ETc adj from soil moisture storage (ΔS).

- Finally, **Soil Water Requirement** (mm) for the previous day (i.e for the previous day, since the rainfall data is completely obtained from previous day 08.30 am to present day 08.15 am) is calculated as,

Soil Water Requirement = TAW – Available Moisture Content

Where,

TAW is Total Available Water (mm)

- The obtained Soil Water Requirement is multiplied with the total cropped area (ha) for the selected parcel.
- The result table provides Soil Water Requirement in terms of m^3 for the selected parcel.
- Display the Farm owner details based on the data fetched for cadastral from result grid view through Data from Bhoomi.

Survey No.	Farmer name	Total area in ha (acre)	Total cropped area in ha (acre)	Crop	Daily rainfall (mm)	Daily surface runoff (mm)	Soil Moisture Content (m^3)

Note: Custom option will allow user to temporarily change the cadastral input values or decision criteria table values for that user session which will help to further execute and analyze DSS results based on these temporary changes.

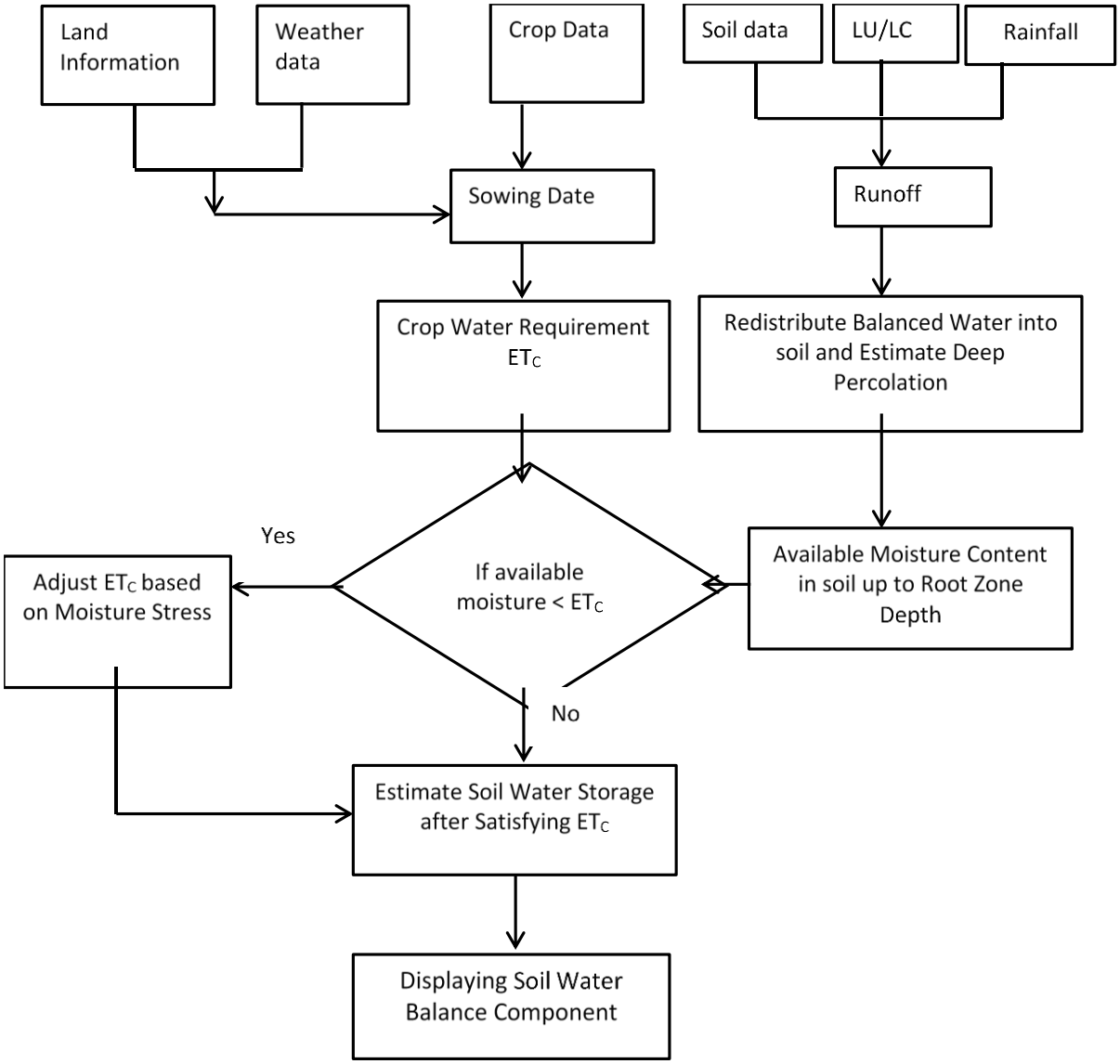

Figure 9.2 Logical flow diagram for the estimation of Soil Water Balance as per the LLDD

Chapter 10

Water Budgeting for Watershed Planning

Water budgeting is critical for the sustainable mangement of available water resoureces at field, watershed or any other scales. It indicates the rate of change in the water stored or available in a watershed based on the demand and supply. It shows the net balance based on the inflow and outflow of water in a year or any selected period of time. The inflow includes precipitation, surface and ground water storage and the outflow includes the drinking water needs of the population, livestock, irrigation, evaporation, runoff, mandatory environmental flow, industrial and other uses. Water budget helps to understand the surplus or deficit status of the watershed, and accordingly helps to design corrective/mitigation measures wherever there is a deficit and plan for the use of surplus water by increasing area under irrigation, livestock and livlihood activities to bring in additional and sustainable benefits to the scociety as a whole. Though water budgets can be worked out at any sclae, ranging from parcel to basins, the present DSS is confined to the datasets required and sequence of activities involved in arriving water budgets at the watsershed scale under Suajal III project.

Table 10.1 Input parameter required for water budgeting

Data base	Required parameter	Master table	Note
Crop water requirement	Details of the land use/cropping pattern and area under different land use		
Water balance component	Rainfall, runoff, soil moisture, ground water recharge		
Demographic details	Human population, livestock population, per capita water consumption for domestic use, livestock use	Human population, livestock population, per capita water consumption for domestic use, livestock use	Information to be compiled from the Census data
Water availability	Existing water resource availability per year	Inventory of water resources-both surface and subsurface water	

Sources for the module:

1. KK Garg, SP Wani, MD Patil: 2016, Simple and farmer-friendly decision support system for enhancing water use efficiency in agriculture: tool development, testing and validation *Current Science*
2. United States Department of Agriculture (USDA), 2012, Soil Survey Manual, Handbook No:18, USDA, USA.

Table 10.2 Step-by-step process for Water budgeting

Sl. No.	Steps	Data requirement
1	Estimate Soil water balance component for selected micro-watershed	Based on the DSS already executed-Soil moisture/water
2	Estimate water availability in micro-watershed using 1. Measured capacities of surface water bodies 2. Runoff generated through watershed based on runoff from Infiltration method 3. Amount of water percolation in soil-ground water (deep percolation component in water balance)	
3	Estimate water required for irrigation based on the crop water requirement and irrigation requirement	
4	Estimate water requirement for household use	Use national standards for human consumption
5	Estimate water required for livestock purpose	Data from livestock census and national standards for their requirement
6	Estimate water required for the existing industrial activities	
7	Estimate water available for irrigation by subtracting water requirement for human and livestock from total water available in micro watershed	
8	Display water budget for micro-watershed and higher levels	

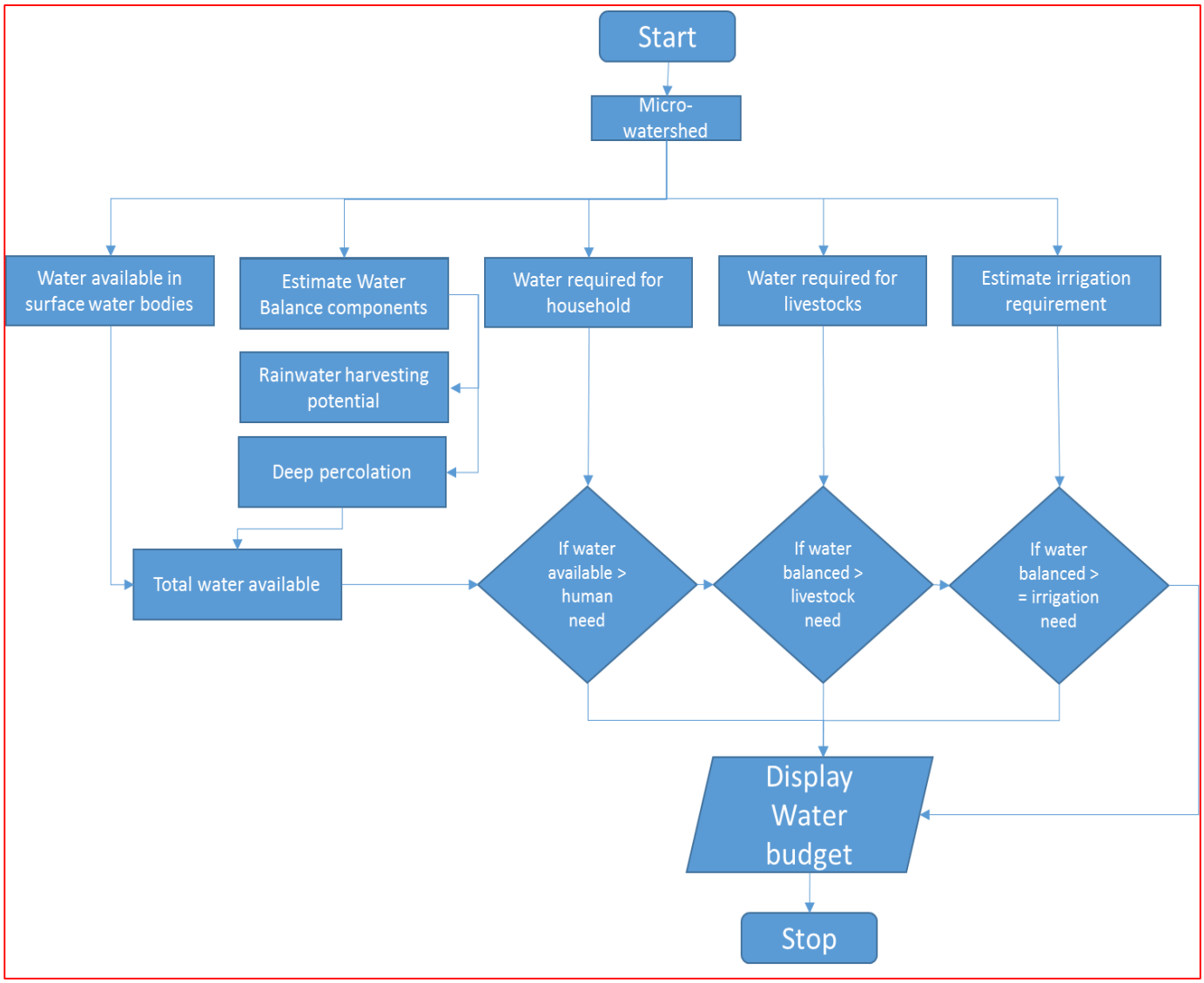

Figure 10.1: Flow chart for Water budgeting as provided in the FRS

Module Description for the development of DSS on Water Budgeting

After successful login, click on 'Water Budgeting' under Decision Support System. A web page for Water Budgeting DSS will be displayed.

- The web page will have the drop-down menu for selecting District, Taluk, Village, Watershed name. The details of input fields in Web page is as mentioned in the section.
- User will select the District, Taluk, Village, Micro Watershed as needed.

1. Establish a link with DSS on Soil Water Balance, water percolation (DP) using DSS for Soil Water Balance.
2. Estimation of total **water availability** in micro-watershed includes
    a. Input from the User regarding volume of Surface Water Bodies (m^3) which can be existing farm ponds, check dams, gokatte, open wells, bore wells etc. Some information is available from LRI, and the rest needs to be collected.
    b. **70% of Runoff** excess after bunding (from DSS on Runoff based on Infiltration method) which is considered for harvesting (m^3)
    c. Ground Water Recharge is also taken as input from the User (m^3). It is available in Hydrology Atlas prepared for the micro watersheds surveyed, or based on the DSS on Soil Water balance, which is the deep percolation component of the DSS.
3. The above three conditions are added up to obtain Total Water Availability in a micro-watershed. This will be the supply side of the water budget.
4. On the **demand side**,
    a. Depending up on the human population (i.e. census data to be used), the water required for human need is estimated (m^3). Also include if any Home Cottage Industry is utilizing water within the selected watershed (m^3) and this is taken as input from the User.

Then this is checked for the condition "If the total water available is greater than Human water need, then check for the Livestock requirement at the watershed level.

    b. Depending up on the livestock population (i.e. livestock census data), the water required for the animal population is estimated (m^3).

The resultant Water Balance is again checked with Livestock need. If it is greater than Livestock need, move to the Irrigation need of the area. Calculate the crop water requirement

of the major crops cultivated in the area by using the DSS on crop water requirement (Water required for irrigation = Crop water requirement + Irrigation losses).

c. If resultant Water Balance is greater or equal to Irrigation need, then display quantity of water as **Available for Irrigation** (m^3).

Display the result in a table showing the information such as Watershed, Total Area in Hectare/Acre, Annual rainfall (mm), Total Available water (m3), Human need (m3), Livestock need (m3), Available water for irrigation (m3).

Note: Custom option will allow user to temporarily change the input values or criteria table values for that user session which will help to further execute and analyze DSS outputs generated based on these temporary changes for that session. This application will facilitate the User to obtain the Water Budget, after meeting the needs of human population, livestock and crops, in the selected watershed on yearly basis, for the current and previous years

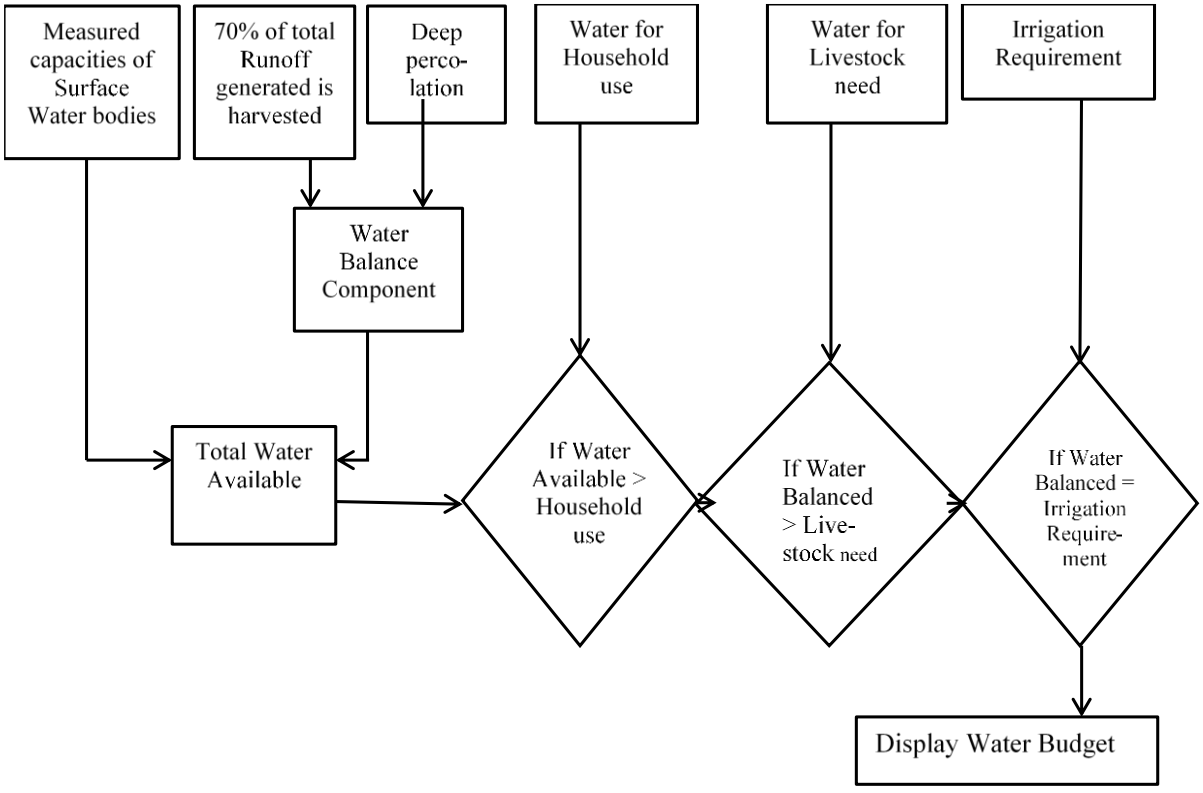

Figure 10.2 Logical flow diagram for DSS on Water Budgeting as elaborated in the LLDD

Annexure 1

List of datasets to be used and their source in the development of DSS

Decision support systems will use data available in LRI Data Center and data from external services for providing the actionable information. Following are available datasets with WDD and its project stakeholders and shall be the part of LRI digital library and Portal:

Maps	• The geo-referenced cadastral maps (1:7,920 Scale) are made available by project partner, Karnataka State Remote Sensing Applications Centre (KSRSAC) for all the watersheds/villages in the state. • KSRSAC also provides required SOI toposheets, available imagery for the project area as and when required to the project partners.
Cadastral maps	• Land parcels are lowest unit of land identification. • For farm or watershed development the ideal base to be used is the cadastral map, owing to the details available at a micro level. • This database includes information such as land parcel number, reference management unit, reference micro-watershed, owner of the land parcel (farmer), area, etc
Satellite imagery	• Cartosat/Quick bird imagery/World view higher resolution imagery
Elevation maps	• Digital Elevation Model (DEM) for the project area.
Geology of the area	• Rock types, lineaments, depth to weathered zone etc, landforms, physiography, elevation, contour
Soil properties	• The important characteristics of the soil needed for planning at the watershed level are collected based on the profile study and laboratory investigations. These include: • Physical o Morphological Characteristics: Soil colour, redoximorphic features like the presence of mottles, nodules, concretions etc. pressure faces/Slickensides, etc o Physical Characteristics: Soil Depth, soil texture (percentage of sand, silt and clay), soil structure, amount of rock fragments, bulk density (g/cm^3), plastic limit, liquid limit, infiltration rate (mm/h), permeability, porosity, soil moisture, water storage (cm/m), available water (cm/m), roots, rooting depth, cracks, etc • Chemical o Soil reaction (pH)-Hydrogen Ion concentration Ratio 1:2.5 water, EC – Electrical Conductivity (1:2.5 Water–mSm-1), exchangeable bases (Calcium, Magnesium, Sodium, Potassium), CEC – Cation Exchange Capacity (cmolkg-1), Exchangeable Sodium Percentage (%), BSP – Base Saturation (%), Fe – Extractable Fe, Major Oxides (%), Calcium

	carbonate (%), Organic carbon (%), Macro Nutrients (%), Micro Nutrients (ppm) • Biological o Amount of fauna/flora, Presence of animals, Soil crusts, etc
Land use / Land Cover	• The land use or land use pattern in different regions of the state has been collected. Details include as under: • Total geographical area , total cropped area, net area sown, cropping pattern of the area, area sown more than once, area under different crops, area under horticulture crops, net irrigated area and area irrigated by different sources like canals, tanks, wells etc., social forestry, agro-forestry, village forest, reserve forest, non-agricultural use, barren lands (Rocky/Stony Waste/Sheet Rocky/ravines, gullied lands,), uncultivated areas, pasture lands, grazing lands, cultivable waste, fallow lands, current fallows, non-agriculture lands (Roads, railways, markets, play grounds, industrial areas, grave yards, habitations, tanks, etc.)
Hydrological data	• The hydrological datasets used for conservation and crop planning are: • Surface runoff, infiltration, evaporation, evapotranspiration, groundwater recharge, sediment load, base flow, water quality, aquifer information etc
Drainage data	• The drainage pattern, or location of water bodies or other features existing at the watershed level are identified with the use of high-resolution imagery used for Land Resource Inventory. • Rivers/streams (entire drainage), all water bodies both perennial and ephemeral (with names of major bodies), Canals, both perennial and ephemeral, springs/ seepages.
Site characterization	• Site characteristics are identified and described in detail as under. • Slope-slope per cent, length and gradient, erosion, drainage, runoff, groundwater depth, flooding, surface fragments, rock out crops, land use etc
Micro-watersheds	• The LRI data is referenced to micro-watersheds. Computations and analytics in the DSS need to be summarised at micro-watershed level. • This database includes information such as watershed code, watershed name, district, GIS layer information, summarized information about land use and land cover, villages, etc.
Management units	• Under each micro-watershed, similar land area is grouped based on soil-site characteristics into homogeneous management units (Soil phases of soil map). • This database includes information such as management unit code, reference watershed code, soil-site characteristics data, village, GIS layer ID, etc
Irrigation related	• Net Irrigated Area, Major and Medium irrigation schemes, Groundwater and Surface water Schemes, Tank commands ,

data	both regularly irrigated and seasonally irrigated, Groundwater irrigated areas, Details of Dug wells (shallow, medium and deep wells), Irrigation potential created due to Dug wells, Lifting device in use, Water distribution device in use, Details of surface flow Irrigation schemes, Irrigation potential created due to surface flow schemes, Constraints in way of full utilization of irrigation potential, Source of finance, Area affected by water logging, salinity and sodicity, Consumption of electricity for lifting water, etc
Crop coverage	• Dynamic database, which stores data of current crop coverage. • This database includes information such as reference land parcel number, reference management unit, reference micro watershed, farmer data, crop sown, area sown, sowing date, harvest date, etc.
Weather data	• The data pertaining to weather and climate- like rainfall, temperature, humidity, wind speed and direction, solar radiation, etc., are available at hobli level for all the 747 hoblies and at gram panchayat level only rainfall data is available for 5628 panchayats in the state. At present there are about 5700 rain gauge stations and 750 automatic weather stations under the control of Karnataka State Natural Disaster Monitoring Centre (KSNDMC). Apart from this IMD maintains about 370 weather stations, Water Resources Development Organisation, GOI about 170 weather stations, and State Agricultural Universities and Research Stations about 100 weather stations in the state. • Location of telemetric rain gauge/weather stations, within the watershed and nearby areas from various agencies • Location of Meteorological station from IMD, within the watershed/or nearby areas • Following are important weather parameters available and recorded in LRI o Rainfall: 15 min interval, daily, weekly and monthly rainfall data (mm) 2. Average weekly, monthly and annual rainfall data (mm), season wise rainfall data (mm), No. of rainy days in a year/season wise, month and week (with 2.5mm and above) o Relative Humidity: daily, weekly, monthly and yearly (%): o Temperature: daily, weekly, monthly and yearly (o Celsius) o Mean Wind Speed: km/h and its direction (in general). o Sunshine: daily, weekly, monthly and yearly (Hrs) o Evapotranspiration: daily, weekly, monthly and yearly (mm)
Socio-economic data	• The required data on various socio-economic parameters, existing infrastructure and marketing facilities for every watershed are collected separately by the LRI partners during socioeconomic survey. • Following are important socio-economic parameters available

	and recorded in LRI: • Census particulars, literacy level, population growth, sex ratio, Land holdings-small, medium and large, Land ownership details, Migration to other areas, Cost of cultivation for major crops, Status of Educational development-literacy rate-male/female and children, Schools, colleges, Technical & Vocational Education School Going Children, Health Centre/Medical Facilities available, etc
Farmer data	• Basic information of farmers will be available in existing government databases like Bhoomi and K-Kisan portal. LRI shall use farmer's data from existing database. • This database includes information such as farmer name, village, taluk, district, contact number, Aadhaar number, etc.
Marketing and infrastructural facilities	• Marketing channels: Farmer to wholesaler, farmer to retailer, farmer to consumer, farmer to mandi, farmer to cooperative Self-Help-Group, farmer to local shops (milk vendor/tea shop etc.), farmer to international market, farmer to farmer, farmer to industry • Marketing Infrastructure: Regulated market (APMC, NAFED, FCI, TRIFED), State Marketing Federations (SMF), Cooperative marketing agencies, local bodies, private, milk and milk products sale centres, HOPCOMS and others. • For each existing marketing infrastructure - Market details, physical structures and facilities available, distance and location.
Communication and Transport Services:	• Road connectivity • Distance from the village to the block, taluk and nearest town • Rail connectivity, Post, Telegraph and Telephone, Internet connectivity • Electricity consumption details, and the gap, • Alternative source of energy-Solar plant, Windmill and Biogas plant • Cooperatives development (type of the society, number of members, paid-up capital, loan details)
Programs and schemes in operation in the project areas	• Date of start of each scheme, pertaining to NRM, under operation in the area, like Integrated Wasteland Development Program, Horticulture Mission, Rashtriya Krishi Vikas Yojana, National Rural Employment Guarantee Scheme, Pradhan Mantri Sinchai Yojana etc.

Annexure 2

SOIL-SITE CHARACTERISTICS CRITERIA

Soil Depth Classes

<25 cm	Very shallow
25-50 cm	Shallow
50-75 cm	Moderately shallow
75-100 cm	Moderately deep
100-150 cm	Deep
>150 cm	Very deep

Soil Texture

a - Sandy
b – Loamy sand
c – Sandy loam
d – Loam
e - Silt loam
f - Clay loam
g - Silty clay loam
h – Sandy clay loam
i – Sandy clay
k - Silty clay
m – Clay

Soil Slope

A- Nearly level (0-1%)
B- Very gently sloping (1-3%)
C- Gently sloping (3-5%)
D- Moderately sloping (5-10%)
E- Strongly sloping (10-15%)
F- Very Strongly sloping (15-25%)
G- Moderately Steeply Sloping (25-33%)
H- Steeply Sloping (33 - 50%)
I- Very Steeply Sloping (>50%)

Erosion

e0 - Nil
e1 - Slight
e2 - Moderate
e3 - Severe
e4 - Very severe

Soil Gravelliness

g0 - Non gravelly (<15 %)
g1 - Gravelly (15-35 %)
g2 - Very gravelly (35-60 %)
g3 - Extremely gravelly (60-80 %)
g4 - Considered as part of the topsoil (>80 %)

Stoniness

Code	Area covered	Class
St1	0.01 to 0.1%	Strong
St2	0.1 to 3%	Very strong
St3	3 to 15%	Extremely strong
St4	15 to 50%	Rubbly
St5	50 to 90%	Very rubbly
St	>90%	Stone

Rocks

No to very few rocks (<2%)	-R0
Fairly rocky (2-10%)	-R1
Rocky (10-25%)	-R2
Very rocky (25-50 %)	-R3
Extremely rocky (50-90 %)	-R4
Rock out crops (>90%)	R5