**3. MATERIAL AND METHODS**

An experiment entitled **“Evaluation of Water Productivity for Improved Soil and Water Management at the Scheme Scale using CropSyst Model”** was carried out during *kharif* and *rabi* season of 2013-14. The details of experimental techniques adopted, criteria used for treatment evaluation and methods followed during the course of investigation are described in this chapter.

**3.1 Site**

The experiment was conducted at village Menawali, in Hanumangarh district of Rajasthan during *kharif* and *rabi* season of 2013-14. Village Menawali is located between 074o20’34”E to 074o20’60” longitude and 28o37’62”N to 29o21’39”N latitude (Fig 3.1 and 3.2). The elevation is approximately 235m above mean sea level. As per NARP classification of agro-climatic zones, Hanumangarh falls in Agro-climatic zone Ib (Irrigated North Western Plain Zone). The general topography of area is almost plain with some isolated steep contours. The soil texture varies from silt loam to silty clay loam. Invariably, all the soils have low organic carbon content.

**3.2 Climate**

The climate of the area is arid. The mean daily maximum temperature during May and June, which is the hottest period, varies from 41 to 46 °C. On individual days, during the hot period, it may rise up to about 49 °C. Hot winds, with low relative humidity, often cause dust storms during the hot season. January is generally the coldest month with a mean daily maximum temperature of 21°C and a minimum 5°C. The average annual rainfall of the tract is about 281.4mm which is mostly received during the rainy season from July to September. During the months of December and January, occasional

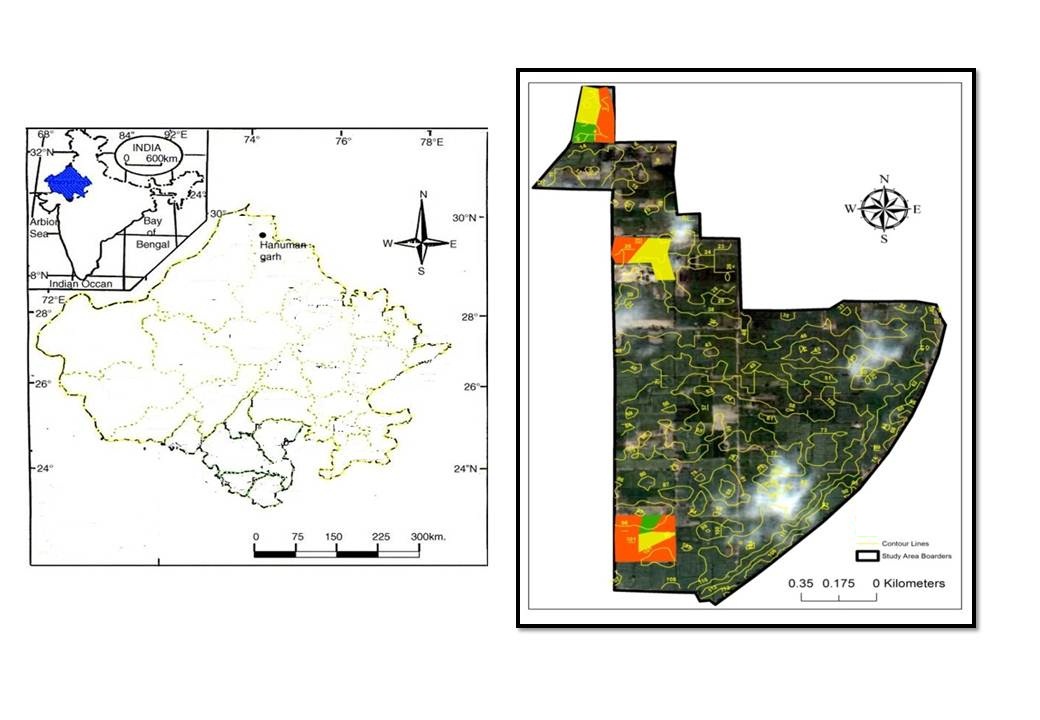
fogs reside in the area. An agricultural year may be divided into four distinct seasons: the hot dry season from March to June, hot rainy (monsoon) season from July to September, post-monsoon season from October to November and cold season from December to February.

The weather conditions prevailed during the period of experimentation (2013-14) were recorded at meteorological observatory of Agricultural Research Sub-station, Sriganganagar, Swami Keshwanand Rajasthan Agricultural University, Bikaner have been given in table 3.1 and graphically depicted in fig 3.3.

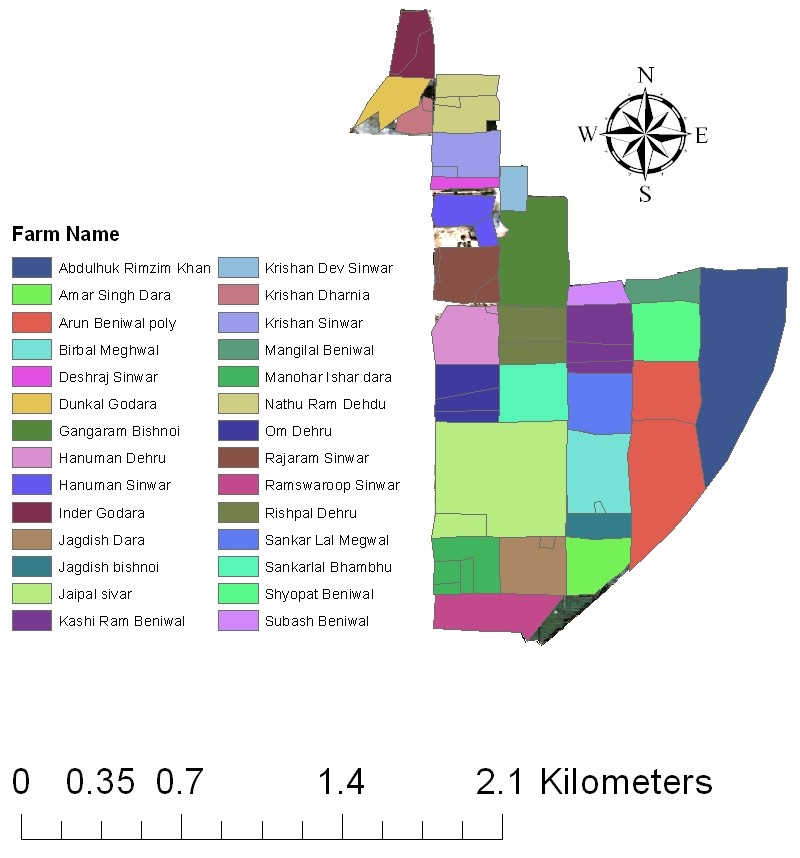
**3.3 Soil**

The soils of the area are alluvial and calcareous in nature formed under arid and semi-arid climate. The soils of site are brown to greyish brown and dark grey in colour, besides being calcareous and slightly alkaline in reaction. These soils are fairly deep and have low permeability.

Soil sampling with an interval of 0-15, 15-25, 25-50, 50-75 and 75-100 cm soil depths, respectively were taken with the help of soil auger crop wise from all the selected farmers fields and were analyzed for physiochemical properties. All the collected soil samples after oven drying, these soil samples were sieved through 2 mm sieve for preparing soil samples with proper labeling. The important soil parameters (Table 3.2 A, B), which were taken into consideration for this purpose, were texture, field capacity, maximum water holding capacity, *pH*, electrical conductivity (*EC*), organic carbon, and mineral nitrogen (N).



**Fig 3.1 (a) Geographical location of Hanumangarh (b) Study area**



**Figure 3.2Demarcation of the field at Menawali, Hanumangarh.**

**Table: 3.1 Monthly meteorological data during crop season 2013-14**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Month** | **Temperature (°C)** | | **Relative humidity (%)** | | **Total Rainfall (mm)** | **Pan Evaporation (mm)** | **Solar Radiation**  **(MJ m-2 d-1)** |
| **Max** | **Min** | **RHMax** | **RHMin** |
| May | 43.5 | 23.9 | 40.8 | 20.0 | 0.0 | 250.2 | 25.4 |
| June | 42.2 | 29.0 | 56.4 | 34.5 | 27.8 | 254.9 | 23.2 |
| July | 40.2 | 28.9 | 70.4 | 55.2 | 80.6 | 207.3 | 21.4 |
| August | 36.7 | 27.4 | 82.1 | 68.8 | 113.7 | 136.9 | 19.6 |
| September | 38.0 | 25.1 | 75.5 | 48.4 | 6.0 | 172.6 | 20.1 |
| October | 35.3 | 20.5 | 81.4 | 50.1 | 0.0 | 105.8 | 15.9 |
| November | 28.5 | 11.0 | 87.5 | 55.0 | 4.5 | 60.9 | 13.2 |
| December | 23.5 | 7.1 | 91.6 | 60.0 | 0.0 | 51.2 | 11.4 |
| January | 20.2 | 5.6 | 94.0 | 60.5 | 0.2 | 38.0 | 11.0 |
| February | 21.9 | 8.0 | 91.3 | 56.4 | 17.1 | 40.0 | 13.9 |
| March | 28.1 | 12.9 | 85.6 | 49.7 | 68.1 | 80.9 | 17.7 |
| April | 35.7 | 18.0 | 65.0 | 32.5 | 8.0 | 149.3 | 21.8 |

# data taken from Agro-meteorological Observatory, A.R.S. (Sriganganagar), SKRAU, Bikaner

**Fig. 3.3 Monthly meteorological data recorded during crop growing 2013-14**

**Table 3.2 (A) Soil physical properties of experimental site**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Layer** | **Thickness (m)** | **Sand**  **(%)** | **Clay**  **(%)** | **Silt**  **(%)** | **Bulk density**  **(g cm-3)** | **CEC**  **(cmol kg-1)** | **pH** | **PWP**  **(m3 m-3)** | **FC**  **(m3 m-3)** |
| 1 | 0.15 | 67.75±6.30\* | 11.14±1.73 | 21.01±4.60 | 1.44±0.06 | 5.39±0.56 | 8.02±0.16 | 0.088±0.01 | 0.189±0.01 |
| 2 | 0.10 | 67.61±6.32 | 11.21±1.75 | 21.17±4.63 | 1.45±0.06 | 5.53±0.55 | 7.94±0.18 | 0.086±0.01 | 0.184±0.01 |
| 3 | 0.25 | 67.45±6.31 | 11.27±1.76 | 21.25±4.67 | 1.46±0.07 | 5.61±0.54 | 8.05±0.21 | 0.085±0.01 | 0.192±0.01 |
| 4 | 0.25 | 67.23±6.26 | 11.41±1.74 | 21.36±4.61 | 1.47±0.07 | 5.77±0.52 | 7.92±0.20 | 0.091±0.01 | 0.188±0.01 |
| 5 | 0.25 | 66.95±6.23 | 11.51±1.72 | 21.58±4.66 | 1.48±0.07 | 5.91±0.58 | 7.88±0.21 | 0.090±0.01 | 0.193±0.01 |

\*Mean±SD.

**Table 3.2 (B) Initial soil conditions of experimental site**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Layer** | **Thickness (m)** | **Water content**  **(m3 m-3)** | **NO3**  **(kg N ha-1)** | **NH4**  **(kg N ha-1)** | **SOM (%)** | **Salinity**  **(dS m-1)** |
| 1 | 0.15 | 0.126±0.028\* | 13.63±1.66 | 23.84±3.66 | 0.290±0.069 | 0.183±0.079 |
| 2 | 0.10 | 0.131±0.028 | 11.57±1.77 | 19.46±3.99 | 0.307±0.075 | 0.183±0.071 |
| 3 | 0.25 | 0.135±0.028 | 9.73±1.88 | 17.64±4.09 | 0.284±0.068 | 0.182±0.067 |
| 4 | 0.25 | 0.139±0.028 | 8.01±1.82 | 16.58±3.94 | 0.265±0.069 | 0.172±0.070 |
| 5 | 0.25 | 0.145±0.029 | 7.45±1.89 | 15.03±4.05 | 0.258±0.069 | 0.174±0.067 |

\*Mean±SD.

In order to ascertain the physico-chemical characteristics, soil samples were collected from different spots of the experimental field in both the season. Representative composite samples obtained from samples of each season, were subjected to physical and chemical analysis separately. The physico-chemical characteristics of the soil of experimental field along with the methods followed for analysis are given in table 3.3.The soils of the area are alluvial and calcareous in nature.

**Table 3.3 Overview of the soil properties data collected for validation**

**Of CropSyst model at farmer fields in Menawali Hanumangarh district**

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Method / source** | **Frequency** | **Purpose** |
| Texture | Hygrometer method | Once | Input derivation |
| Bulk density | Core Method | Once | Input derivation |
| Soil moisture | TDR | Before and after irrigation | Calibration and validation |
| pH | In soil-water suspension of 1:2 by pH meter | Before sowing | General |
| Electrical Conductivity | In soil-water suspension of 1:2 by Conductivity  Meter | Before sowing | Calibration and validation |
| Organic Carbon  Cation exchange  capacity | Wet digestion method (Walkley and Black, 1934)  Sodium Index method | Before sowing  Before sowing | Input derivation  Input derivation |

**3.4 Selection of farmers**

Selection of farmers was done on the basis of major cropping sequence grown in the study area. A general survey of 28 farmers’ fields was done out of which 15 farmers were selected keeping in view the irrigation facilities from the IGNP canal for model calibration in 2012-13, thus farmers again were taken for validation too in 2013-14. The fields of farmers are depicted in Fig 3.2. The list of farmers along with their crop grown is presented in Table 3.4.

**3.5 Area under cultivation**

Total area of the experimental site was 187 ha out of which net cropped area were 170 ha Average land holding of 6.1 ha. Major crops of the area were cotton and clusterbean during *kharif* and wheat and mustard in *rabi*. Majority of farmers (about 80%) grow cotton and wheat in *kharif* and *rabi* season, respectively. About 18-20 % cropped area was under cluster bean and mustard during *kharif* and *rabi* season, respectively

Table 3.4 List of selected farmers for validation along with their Crop grown

|  |  |  |  |
| --- | --- | --- | --- |
| **Farmer No.** | **Farmer Name** | ***Kharif Crop* (% Area)** | ***Rabi Crop* (% Area)** |
| 1 | Indra Godara | Cotton (44.2)  Cluster bean (55.1)  Fodder Bajra (0.7) | Wheat (44.4)  Barley (55.0)  Fodder Barseem (0.6) |
| 2 | Dhunkal Godara | Cotton (99.2)  Fallow (0.8) | Wheat (79.2)  Mustard (20.0) Fallow (0.8) |
| 3 | Krishan Dharnia | Cluster bean (99.3)  Fodder Bajra (0.7) | Wheat (74.5)  Mustard (24.6) Fodder Barseem (0.9) |
| 4 | Nathu Ram Dehru | Cotton (58.2)  Cluster bean (41.4) Fodder Bajra (0.4) | Wheat (58.2)  Barley (41.4) Fodder Barseem (0.6) |
| 5 | Krishan Sinwar | Cluster bean(99.5) Fallow (0.5) | Wheat (80.4)  Mustard (19.1) Fallow (0.5) |
| 6 | Deshraj Sinwar | Cluster bean (99.4) Fodder Bajra (0.6) | Mustard (100) Fodder Barseem (0.6) |
| 7 | Krishan Dev Sinwer | Cluster bean (99.7) Fallow (0.3) | Mustard (99.7) Fallow (0.3) |
| 8 | Gangaram Bishnoi | Cotton (70.1)  Cluster bean (29.3) Fodder Bajra (0.6) Fallow (0.3) | Wheat (68.2)  Mustard(30.9) Fodder Barseem (0.6) , Fallow (0.3) |
| 9 | Hanuman Sinwer | Cluster bean (99.6)  Fodder Bajra (0.4) | Barley (99.5) Fodder Barseem (0.5) |
| 10 | Rajaram Sinwer | Cotton (55.4)  Cluster bean (44.3) Fallow (0.3) | Wheat (99.7)  Fallow (0.3) |
| 12 | Subash Beniwal | Cotton (99.6) Fallow (0.4) | Wheat (66.5)  Barley (33.1) Fallow (0.4) |
| 13 | Mangilal Beniwal | Cotton (99.5) Fodder Bajra (0.5) | Wheat (99.5) Fodder Barseem (0.5) |
| 18 | Richhpal Dehru | Cotton (79.2)  Cluster bean (20.1) Fallow (0.7) | Wheat (80.0)  Mustard (19.3) Fallow (0.7) |
| 19 | Hanuman Dehru | Cotton (58.3)  Cluster bean (41.1) Fallow (0.6) | Wheat (99.4) Fallow (0.6) |
| 20 | Om Dehru | Cluster bean (99.7) Fallow (0.3) | Wheat (99.6) Fallow (0.4) |

**3.6 Sampling, measurement and analysis**

Most of the input parameters of CropSyst are site specific, and obtained by field measurements. Some of the input parameters such as soil hydraulic parameters are difficult to measure directly under field conditions, and hence determined through the validation of the model. The validation of CropSyst requires detailed crop measurements under field conditions.

The various observations required for model calibration were collected from farmer’s field crop wise. The required input parameters can be categorized into meteorological, soil, water and crop parameters. These measurements were used to validate of CropSyst model.

### 3.7 Crop and cropping sequences

In this region there are more than 6 different types of crops grown like*: Cotton (Gossypium hirsutum), Clusterbean (Cymopsis tetragonaloba), Pearlmillet (Pennisetum glaucum), Wheat (Triticum aestivum), Mustard (Brassica Juncia),* and Barley (*Hordium vulgares)*, out of which maximum area is under cotton. Wheat is next most popular crop among farmers living in the region. It was observed that 75% of the population was engaged in agriculture. The major crop sequences/rotations followed in Menawali region of Hanumangarh district are cotton-wheat for one year rotation. The major fruit crops of the district are Malta (*Citrus sinensis), Mandarin (Citrus reticulate) and grapes (vitis vinifera)*.

**3.7.1 Crop management practices**

The details of crop management practices adopted for various crops at study site areas under:

**3.7.1.1 Cotton**

The management practices of cotton adopted by the farmers in the study area are presented in AnnexureI. The tillage operation were ploughing, harrowing followed by cultivator and planking. Sowing was done between first week to last week of May. Seed rate used by the farmer range between 2.2 to 2.8 kg ha-1 with a spacing 60x 45 cm by hand plough. Half dose of Nitrogen (N) and full Phosphorus (P2O5) was applied as basal and remaining half dose of Nitrogen (N) was top dressed at 30 DAS.

**3.7.1.2 Clusterbean**

Annexure II shows the management practices of clusterbean adopted by the farmers in the study area. The tillage operation was ploughed, harrowing followed by cultivator and planking. Sowing was done between second week May to middle of June. Seed rate used by the farmers range between 14 to18 kg ha-1with a spacing of 30x10 cm by seed drill. Full dose of nitrogen (N) and phosphorus (P2O5) was applied as basal application.

**3.7.1.3 Wheat**

Annexure III shows the management practices of wheat adopted by the farmers in the study area .The tillage operation were ploughing, harrowing followed by cultivator and planking. Sowing was done between first week November to last week of December. Seed rate used by the farmer range between 80 to120 kg ha-1with a spacing of 20 x 5 cm by seed drill. Half dose of nitrogen (N) and full phosphorus (P2O5) was applied as basal and remaining half dose of nitrogen (N) was top dressed at 30 DAS.

**3.7.1.4 Mustard**

Annexure IV shows the management practices of mustard adopted by the farmers in the study area. The tillage operation were ploughing, harrowing followed by cultivator and planking. Sowing was done between last week of October to second week of November. Seed rate used by the farmer range between 3 to 6 kg ha-1 with a spacing of 30x10 cm by seed drill. Half dose of nitrogen (N) and full phosphorus (P2O5) was applied as basal and remaining half dose of nitrogen(N) was top dressed at 30 DAS.

**3.7.1.5 Barley**

Annexure V shows the management practices of barley adopted by the farmers in the study area. The tillage operation were ploughing, harrowing followed by cultivator and planking. Sowing was done on 15 December. Seed rate used by the farmer was 100 kg ha-1 with a spacing of 20x5 cm by seed drill. Half dose of nitrogen (N) and full phosphorus (P2O5) was applied as basal and remaining half nitrogen(N) was top dressed at 30 DAS.

**3.7.2 Plant studies**

For measuring physiological parameters three sampling area in each crop of each farmers were selected. For cotton the area of each sampling area was 1 x 1 m, whereas in other crops an area of 0.50 m x 0.50 m were selected for measuring GAI and AGY. For measuring yields an area of 1x1m area were selected for each crop. For measuring rooting depth, the five plants of each crop from ten farmers were used (Table 3.5).

**Table 3.5 Overview of the plant growth data collected for validation of CropSyst model at farmer fields in Menawali Hanumangarh district**

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Method / source** | **Frequency** | **Purpose** |
| Crop development stage (in days after sowing) *i.e*. emergence, panicle initiation, anthesis, maturity and harvest | Field observation | 4 times | Input derivation |
| Plant density | Field observation | 4 times | Input derivation |
| Leaf area | Field observation | 4 times | Calibration |
| Rooting depth | Field observation | 2 times | Input derivation |
| Crop yields | Field observation | at Harvest | Validation |

**3.7.2.1 Leaf area**

The leaves from plants selected for growth analysis from each field were used for the estimation of leaf area. Leaf area was computed by leaf area meter and expressed as cm2per square meter.

**3.7.2.2 Specific leaf area (SLA)**

The Specific Leaf Area was calculated as follows:

Leaf area (cm2)

SLA = ------------------------------

Leaf dry weight (g)

**3.7.2.3 Leaf biomass**

The leaves from plants for analysis were put in butter paper and kept in hot air over at 85 ± 10 C for 24 hours. The dry weight of the leaves was recorded and expressed in grams.

**3.7.2.4 Days to emergence**

Plants were observed for emergence. The day on which 50 per cent of plants showed emergence in the fields was considered as emergence. The number of days taken from the date of sowing to emergence was determined and expressed in number as days taken for emergence.

**3.7.2.5 Days to 50 per cent flowering**

The day on which 50 per cent of plants showed flowers in the fields was considered as 50 per cent flowing. The number of day taken from the date of sowing to flowering was determined and expressed in number as days taken for 50 per cent flowering.

**3.7.2.6 Days to 50 per cent grain filling**

The day on which 50 per cent of grainsfilled in the fields was considered as 50 per cent grain filling. The number of day taken from the date of sowing to grain filling was determinedand expressed in number as days taken for 50 per cent grain filling.

**3.7.2.7 Days to maturity**

The day on which 50 per cent of plants showed maturity in the fields was considered as maturity of plants. The number of days taken from the date of sowing to maturity was determined and expressed in number as days taken for maturity.

**3.7.2.8 1000 - seed weight**

A small seed sample was taken from the produce of each of the net plot harvested and 1000-seeds were counted and their weight was recorded as test weight (g).

**3.7.2.9 Seed yield**

The seed yield of each net plot was recorded in kg plot-1 after cleaning the threshed produce and was converted as kg ha-1.

**3.7.2.10 Straw yield**

Straw yield was obtained by subtracting the seed yield kg ha-1 from biological yield kg ha-1. In case of cotton, seed + cotton is taken as economic yield.

**3.7.2.11 Biological yield**

The harvested material from net area of each plot was thoroughly sun dried. After drying, the produce of individual net plot was weighed with the help of a spring balance and recorded in kg plot-1. Later this was converted into kg ha-1.

**3.7.2.12 Harvest index**

The harvest index was calculated by using following formula and expressed as percentage (Singh and Stoskopf, 1971).

|  |  |  |
| --- | --- | --- |
| Harvest index (%) = | Economic yield | x 100 |
| Biological yield |

**3.7.2.13 Nutrient content and uptake**

The representative samples of seed and straw drawn at the time of threshing and winnowing were ground and analyzed for nitrogen(Snell and Snell, 1949), phosphorus(Jackson, 1973) and potassium(Jackson, 1973) concentration.The uptake of nitrogen, phosphorus and potassium after harvest in seed and stover was estimated by using the following relationship:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Nutrient uptake =  kg ha-1 | Nutrient content in seed (%) | x | Seed yield kg ha-1 | + | Nutrient content in stover (%) | x | Stover yield kg ha-1 |
| 100 | | | | | | |

### 3.8 Irrigation

In the study area, the source of irrigation is the IGNP canal. The method used for discharge, duration and depth of irrigation and frequency are presented in Table 3.6.

**Table 3.6 Overview of the irrigation data collected for validation of CropSyst model at farmer fields in Hanumangarh district**

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Method / source** | **Frequency** | **Purpose** |
| Discharge of Irrigation source i.e.canal water | V notch | 4 times | Input derivation |
| Duration of irrigation | Field observation | Each irrigation | Input derivation |
| Irrigation depth | Calculated by multiplying the discharge and duration of irrigation and divided by field area. | Each irrigation | Input derivation |

**3.9 Model description**

CropSyst model has been chosen for this project. It is a multi-year, multi-crop, daily time step cropping systems simulation model developed to serve as an analytical tool to study the effect of climate, soils, and management on cropping systems productivity and the environment. Emphasis has been placed on developing a user-friendly interface, providing links to GIS software, a weather generator, and other utility programs. CropSyst simulates the soil water budget, soil plant nitrogen budget, crop phenology, canopy and root growth, biomass production, crop yield, residue production and decomposition, soil erosion by water, and salinity. These processes are affected by weather, soil characteristics, crop characteristics, and cropping system management options including crop rotation, cultivar selection, irrigation, nitrogen fertilization, soil and irrigation water salinity, tillage operations, and residue management.

The development of CropSyst started in the early 1990s. The motivation for its development was based on the observation that there was a niche in the demand for cropping systems models, particularly those featuring crop rotation capabilities, which was not properly served. Efficient cooperation among researchers from several world locations, a free distribution policy, active cooperation of model developers and users in specific projects, and careful attention to software design from the onset allowed for rapid and cost-effective progress. Another important factor was the advantage of learning from a rich history of crop modeling efforts.

CropSyst was designed to draw from the conceptual strengths of EPIC, but including a more process-oriented approach to the simulation of crop growth and its interaction with management and the surrounding environment. In addition, a stronger emphasis on software design was a clear departure from the EPIC and DSSAT approaches. Attention to a balance between the incorporation of sound science in the models and the utilization of adequate software design practices has been a trait of CropSyst since the beginning of its development. In this regard, it shares somewhat common objectives with APSIM (McCown*et al*., 1996; Keating *et al*., 2003), a modeling approach that has evolved to place substantial resources in the development of quality software engineering practices. CropSyst model will be applied to carry out the research study.

The model has been developed to serve as an analytic tool to study the effect of cropping systems management on productivity and the environment. The model simulates the soil water budget, soil-plant nitrogen budget, crop canopy, root growth, dry matter production, yield, erosion, residue production and decomposition. Management options include: cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, tillage operations (over 80 options) and residue management.

The CropSyst model has a main driver program, a land unit module and modules for the primary components that make up a land unit in a cropping system (Fig. 3.4). The primary modules are for weather, soil, plant, soil-plant-atmosphere interface, and management components. Collectively, these components describe the time changes in the soil and plants that occur on a single unit in response to weather and management. Summary descriptions of management module are described in Table 3.7.

**3.10 Model validation**

CropSyst model was calibrated for kharif and rabi season crops (cotton, clusterbean,wheat, barley and mustard) in 2012-13. The calibrated model was validated during 2013-14 for the site conditions using the crop model parameter values calibrated as mentioned years with associated water management. Soil characteristics, initial conditions of available soil water, nitrogen and organic matter and daily weather data were model input data for CropSyst as observed in the experiment. Model evaluation and validation was conventionally made by comparing simulation outputs with observed and simulated data. The CropSyst model was validated using the field experiment data conducted in 2013-14 growing season. It was validated for aboveground biomass (AGB), grain yield, N-uptake and green area index (GAI). The difference measures include the root mean square error (RMSE) and index of agreement (IoA). Taking into account difference in some physiological characteristics of crop varieties, validation for each crop was carried out variety wise. However here we give generalized statistical measures for separate crops.



**Figure 3.4: Overview of components and modular structure of CropSyst model (Stockle*et al.* 2003)**

**Table 3.7: Summary description of management module**

|  |  |
| --- | --- |
| Planting | Determines planting date based on read-in value or simulated using an input planting window and soil, weather conditions |
| Harvesting | Determines harvest date, based on maturity, read-in values or automatic applications based on soil water depletion |
| Irrigation | Determines daily irrigation, based on read-in values or automatic applications based on soil water depletion |
| Fertilizer | Determines fertilizer additions, based on read-in values or automatic conditions |
| Residue | Application of residue and other organic material as read-in or simulated in crop rotations |

**3.11Statistical analysis**

**3.11.1 Water balance**

The field water balance can be written as

P= E + T + R + D + S – I

Where, P is precipitation, E is soil evaporation, T is crop transpiration, R is surface runoff, D is drainage, S is change in soil water storage and I is irrigation.

**3.11.2 Water use efficiency**

Water use efficiency (WUE) was defined as

|  |
| --- |
| Y |
| ET |

WUE =

(kg ha-1 mm)

Where, WUE represents water use efficiency for the grain yield (kg ha-1), Y is the grain yield and ET is the evapo-transpiration during the growth period.

**3.11.3 Root Mean Square Error**

Root mean square error is used to test the error between simulated and observed values. The expression of RMSE is



**3.11.4 Correlation coefficient**

A measure that determines the degree to which two variable's movementsareassociated.  
  
The correlation coefficient is calculated as:



**3.11.5 Index of agreement**

The index of agreementis used to pondered percentage of the criteria to which the alternative is preferred to alternative and is calculated by

