Turning Basaltic Terrain into Model Research Farm: Chronicle Description

ICAR-National Institute of Abiotic Stress Management
(Indian Council of Agricultural Research)
Malegaon, Baramati - 413 115, Pune

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Preface

Indian agriculture is confronting with the dichotomous challenges of food security and sustainability within finite land and water resources and impending climate changes. Thus, providing vistas from science of land-water-environment continuum suiting to the societal needs for food security remains a plausible option. Keeping this in view, ICAR established National Institute of Abiotic Stress Management (NIASM) for undertaking research related to impacts of abiotic stresses on crop production, livestock and fisheries and exploring long-lasting options for their adaptation and mitigation strategies at Malegaon, Baramati, Pune. Indeed, the site reflected multiple soil edaphic stresses, frequent droughts and its susceptibility to climate changes in an undulating rocky (basalt) terrain, devoid of any vegetation under the rain-shadow environment, developing an agricultural research farm was really an uphill task. Hence, design and development of farm in this fragile setting was vital for understanding the interplay of natural and anthropogenic factors on one hand and progressive introduction of sustainable technologies for enhancing productive potential of resources on the other assumed paramount importance. Moreover, addressing the problems of low soil fertility, severe erosion and loss of organic matter, desertification, salinization and vulnerability to climate change was on forefront in creation of the agro-ecological model research farm.

After meticulous understanding of the site, a schematic layout was planned for multidisciplinary researches conforming to the mandate of the Institute. Guiding and supervising each and every development of the erstwhile barren grazing land to a state-of-the art "Model research farm" is a matter of great pride and satisfaction. Initially, this mammoth task seemed like 'dream impossible' but with a team of determined, hardworking and dedicated scientists and technicians who toiled stupendous efforts beyond call of duty in making 'dream fulfilled' in less than three years. Hence, once considered as insurmountable challenge, opportunities beckon now for conducting world class researches in this hitherto not much explored area of abiotic stresses in this research farm. This also sounds other stakeholders and practitioners for converting large tracts of barren lands in the country into arable farming.

This bulletin aptly covers various activities and processes of farm development in a sequential mode by narration and depicting the same through photographs for understanding the chronicle activities. I am sure that this saga of transformation at ICAR-NIASM will be a guide and source of inspiration not only for other upcoming institutions and establishments but for millions of farmers of Deccan plateau having similar physiographic settings.

9th February, 2015

(P.S. Minhas)

Executive Summary

NIASM, the unique institute of ICAR, was set up on 21 February, 2009 at Baramati representing the rain shadow area after the Sahyadri Ranges frequented by famine calamities. The 56.5 ha of barren land allotted to the institute was having shallow 0.1–0.3 m *murrum* soil with parental basaltic rock. With the objective of developing a "Model Research Farm" for demonstrating soil and water conservation technologies and for multi-disciplinary and multi-commodity basic and strategic research on abiotic stressors, the work started with a generation of a contour map. The land has relatively steeper slopes (4%) towards east from the central peak while it is sloping gently (1.8%) towards south. Since there was hardly any soil on the surface, the land development presented a gigantic challenge.

The research farm was designed for an area of 40 ha based on scientific considerations like watersheds, natural drainage pattern, topography, contour map and layout of various buildings etc. The south side farm (16 ha) is divided into six blocks which are sub-divided into 37 rectangular/trapezoidal plots including agro-met observatory and fish ponds. Since the acquired land was a rocky (basalt) terrain devoid of any vegetation, this was blasted, ripped and levelled with the help of heavy machinery support from the Irrigation Dept., Maharashtra. Locally available spent wash was applied to further pulverize the gravelly *murrum*. The plots were then finally leveled with front dozer tractors. Since the virgin soils were still gravelly and low in fertility (OC 0.07%; Av-P 0.5 kg/ha), heavy additions (30-40 brass/acre) of spent mushroom substrate/ FYM were made. In addition, 2.7 ha area has been filled-in by transporting black/tank silt soil. North-east side farm (8 ha; initially 4% slope) has been developed into three blocks of five terraces (width 35-38 m) while 4 ha of north-west side farm including a water balancing tank has been developed into two blocks having 7 research plots. Research activities to evolve long lasting solutions for the adverse impacts of abiotic stresses on crop production, livestock and fisheries have been initiated on south-farm. Both the north-east and north-west farms have been put under orchards to address edaphic stress and drought related issues.

The only source of irrigation water is Nira canal flowing at about 0.5 km south of the institute. To cover the whole farm under auto-irrigation, a lift irrigation scheme that includes water balancing tanks, pump houses, remotely controlled auto-irrigation units etc have been planned. But to overcome the current water scarcity, a part of south-side farm has been put under rainfed grasses/fodders/trees while only the low water requiring/drought tolerant orchards are being tried on north-east/west-side farms. A noteworthy achievement has been the re-use of boulder (about 38,000 m^3) and *murrum* of excavated tanks/ponds (7600 m^3) for the base of institute's roads/farm paths. This has not only saved upon their disposal costs but otherwise if procured, the exchequer should have incurred about Rs. 2 crores.

1. Introduction

Farmers, scientific communities and policy makers have always been concerned about adverse impacts of abiotic stresses on agriculture. An average of 50 % yield losses in agricultural crops are caused by abiotic factors mostly shared by high temperature (20 %), low temperature (7 %), salinity (10 %), drought (9 %), and other forms of stresses (4 %). However, the renewed and immense concerns about abiotic stresses have emerged from their increasing intensity, adverse impacts with climate change and over exploitation of natural resources. As proportions of productive lands are gradually declining with anthropogenic activities, it is axiomatic that the food security for ever increasing population would have to be met through adaptation and mitigation strategies for harsh agro-ecosystems in order to sustain productivity of agricultural commodities viz., crop plants, livestock and fisheries, especially in arid and semi-arid regions.

Sensing the unfavourable environment of increasing abiotic stresses dawning upon poverty riddled Indian agriculture, the Moily Oversight Committee recommended establishment of a dedicated research institute on abiotic stress management. Thereafter, the proposal by Ministry of Agriculture was approved by the Union Cabinet in XI Plan to establish "National Institute of Abiotic Stress Management (NIASM)" with a legal status of 'Deemed-to-be-University' under the Indian Council of Agricultural Research. In this context, when the proposal came to the then chief minister of Maharashtra Shri. Vilas Rao Deshmukh on 5 May, 2008, he readily offered to Shri Sharadchandraji Pawar, the then Hon' Minister of Agriculture and Food Processing, Government of India to host the institute at Baramati, Pune District, Maharashtra.

The land proposed by the state government for establishment of the new institute was in Gat No. 35, village Malegaon Khurd, taluka Baramati, district Pune admeasuring 76.49 ha. Out of this Gat, 56.49 ha were offered for this institute. The site had very shallow basaltic rocky land and was not under cultivation. Even the growth of grasses was very restrictive. The actual land site proposed was classified as grazing land by the local administration. It was used for grazing mainly by small ruminants during monsoon season by Dhangars (nomads). Wild deer and rabbits were the regular visitors. A committee constituted by ICAR vide letter no. 1-26/2008/IA-II (dated 8th May, 2008) visited the proposed site offered by the Government of Maharashtra and on considering several factors submitted its report regarding the suitability of the land for establishment of the institute. The council perceived all these issues and established the National Institute of Abiotic Stress Management on the site. It is in the midst of an agriculturally diversified belt representing a rainfall shadow area with soils varying from light to heavy. On 29 January, 2009, the Ministry of Agriculture released the press notification regarding the formation of this institute with a budget allocation of Rs. 73.5 crores in the XI plan. The foundation stone for the institute was laid on 21 February, 2009 by Shri Sharadchandraji Pawar. On 31 December 2009, the boundary of 56.49 ha inclusive of the sarvajanik road and an area under MSEB power sub-station was marked and handed over to the Director, NIASM by the revenue department as a single piece, leaving all the encroachments and a 30 feet wide road outside the boundary. Additional area of about one ha beyond the south-end boundary was also set aside for shifting of electrical sub-station from within the institute land. The original offer of 30 year lease was enhanced to 99 years and mutation in the 7/12 revenue extract was made. A lease amount of Rs 99/- @ Rs 1 per annum for 99 years towards the above land was also paid.

After being established as a new institute, intensive efforts have been made in planning and execution for the development of a "Model Research Farm" to take up various basic and strategic researches on different enterprises namely crops, livestock and fisheries.

2. Location and Climate

Institute is located at 18° 09′ 30.62′′N; 74° 30′ 03.08′′E; MSL 570 m at Malegaon khurd, Baramati in Pune district of Maharashtra state. Baramati is situated in the eastern part of Pune district which is a part of the Desh or Western Maharashtra region. It falls under the agro-ecological region Deccan Plateau, hot and semi-arid climate (AER-6) and agro-climatic zone AZ-95 i.e. scarcity zone of Maharashtra. The long-term average annual rainfall is 560mm, and this is restricted to south-west and retreating monsoon. Because of low rainfall, the soils in the area are shallow and poorly developed. Major agricultural area is rainfed except for about one-third of Baramati area along the Nira canal that is irrigated and mainly supports sugarcane. Agricultural drought is a common phenomenon in the area.

Long-term analysis of weather data of Baramati (1986-2011) reveals that mean monthly temperature varies between 22 °C (Dec) and 31.4°C (May). Daily maximum temperature becomes highest in the month of May (39.1 °C) and lowest during December (29.8 °C). Similarly, in case of daily minimum temperature too, May and December are the months when the highest (23.7 °C) and lowest (14.2 °C) values occur respectively. Morning time relative humidity measured at standard prescribed hour of 0700 Local Mean Time (LMT) varies between 81% (Jul and Sep) and 55% (Apr) and the annual average is 73%.

Wind direction analysis of the recent years has shown that during the summer monsoon season (June-Sep) wind mostly blows from the westerly directions, west of south-west or west of north-west. The month of October represents a transition between westerlies and easterlies. November and December are frequented by both northerly and easterly winds. During the rest of the months, i.e. January- March north-westerly as well as easterly and south-easterly winds remain most prevalent. During January-March wind speed averages around 5-6 km/h, then gradually increased through April and May. During the monsoon months of June to September average wind speed is around 11 km/h or more and sharply falls during October onwards.

Annual rainfall during the period 1986-2011 averaged 584.1 mm. Contribution of southwest monsoon (June-September) and post-monsoon (October-December) rainfall is about 70 and 21%, respectively. During the monsoon season, the maximum rainfall is received normally during September (159.1 mm) followed by June (113.1 mm). In the post-monsoon season, the maximum rainfall normally occurs in October (104 mm) followed by November (13.7 mm) and during the summer season in May (39.6 mm). Normal rainfall for July and August is 65.3 and 71.3 mm, respectively. Other months of the year, viz. December to April together receive rainfall between 10-15 mm only. Rainfall variability in the post-monsoon season is 87% and that of the southwest monsoon season is 38 % while for the annual rainfall, CV is about 37%. Effective rainfall is received only during the period May-October. Annual Class A open pan evaporation is 1965 mm which is about 3 times the rainfall. The maximum evaporative demand occurs in the month of May (280.8 mm) whereas the lowest in December (111.3 mm). Monthly climatic conditions with respect to important parameters are depicted in Fig. 1.

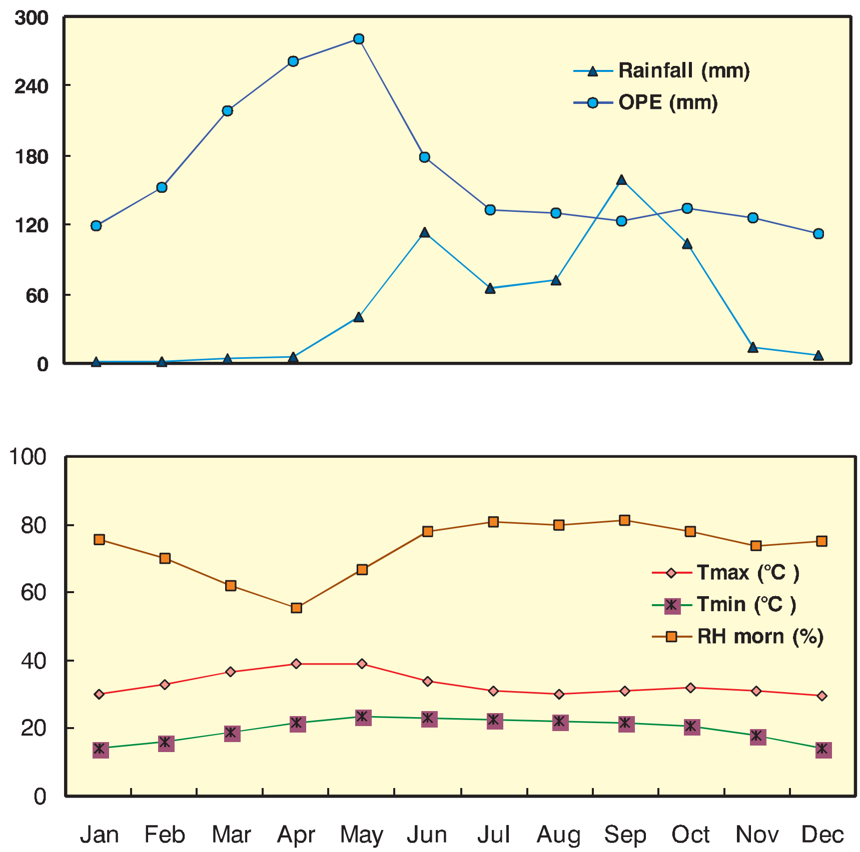


Fig. 1. Rainfall, open pan evaporation, temperature and relative humidity during 1986-2011

Variability in rainfall over the past 26 years was assessed based on the rainfall deviation from the long term average value. Following the IMD criteria, years were classified into four rainfall groups, viz. excess (> 20 %), normal (19 to -19 %), deficit (-20 to -59 %) and scanty (< -59 %). Number of years in each category and extreme rainfall years and its intensity l that occurred in the southwest monsoon (Jun-Sep) and post monsoon (Oct-Dec) seasons are presented in table 1.

Table 1. Rainfall extremes and no. of years/seasons under various rainfall classes

Season	Number of years in rainfall category				Rainfall Total (mm)	
	Excess	Normal	Deficit	Scanty	Highest (year)	Lowest (year)
SW Monsoon (Jun-Sep)	7	10	8	1	762 (2010)	151 (2003)
Post-monsoon (Oct-Dec)	9	3	3	11	410 (1993)	0 (2003)
Annual Rainfall	5	14	6	1	1125 (2009)	151 (2003)

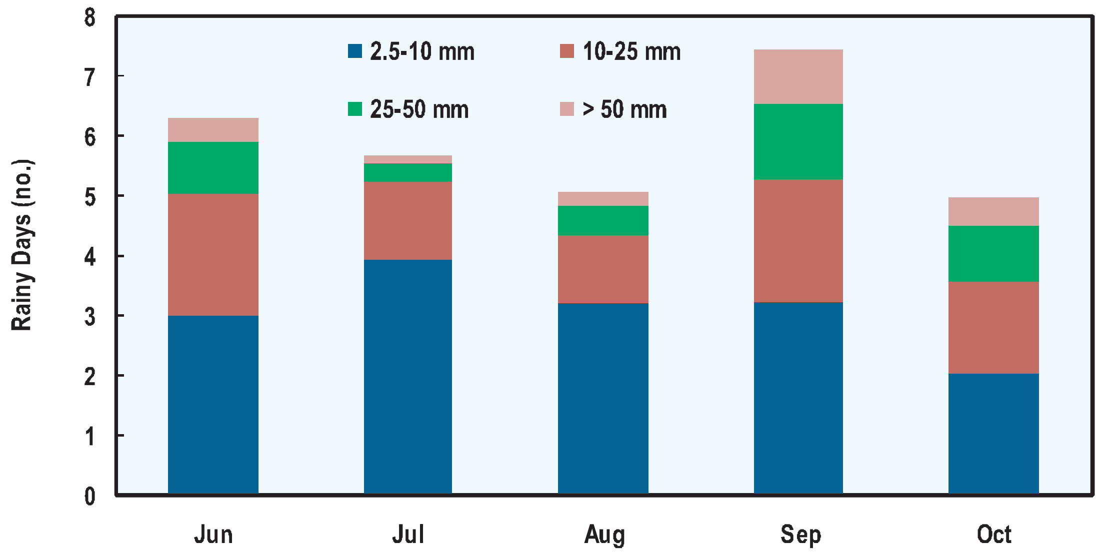


Fig. 2. Normal rainfall intensity distribution in various rainy months

The average number of days with rainfall > 2.5 mm range between 5 -7 during the June to October. However, the heavy precipitation events occur more during September, June and October than July and August which result in lesser total rainfall during the later months (Fig.2). SW-monsoon rainfall is showing a slight increasing trend (R^2 = 0.15*) while no trend was obvious in post-monsoon or annual rain. Month-wise analysis of rainfall intensity indicated an increase in the rainfall intensity categories of > 2.5 mm (R^2 = 0.35**) and 10-25 mm (R^2 = 0.41**) during August while same was also obvious in 10-25mm rainfall intensity for annual (R^2 = 0.14, P = 0.06).

3. Geo-morphology of the Site

The close of Mesozoic era (upper cretaceous) was marked by the out pouring of enormous lava flows and continued till the end of early Eocene that is about 75 million years which was the active period of volcanism in Indian subcontinents. These lava flows spread out as nearly horizontal sheets, ranging in thickness from a few to over 100 feet, form flat topped plateau with step like terrace and covering an area of about 2,00,000 square miles. These are commonly called as traps rock with dominantly basaltic composition and formation as a whole is known as Deccan traps (Fig.3). The traps have been divided in to three groups - upper (450 m), middle (1200 m) and lower (150 m thick) with intra-trappean beds at their base and are unevenly distributed in the Deccan plateau. Institute site is a part of the middle trap formation with inter-trappeans and paleosols in the lower horizons.

The soils/rock exposed in the region range in age from recent to Cretaceous-Eocene (Fig.4). The recent rocks are represented by shallow alluvium and black cotton soil. The Quaternary is represented by shallow alluvium and black cotton soil with the consolidated sediments exposed in the downstream areas. Two lava flows of varying thickness and morphology belonging to the Deccan Trap are exposed. The lower most flow is grey, fine grained jointed and simple. The upper flow has been removed by denudation and weathering action. The upper flow is pinkish vesicular and belongs to the hummocky phoebe type. The flow is strongly compound and consists of lava toes meter scale lobes and thick (~10 m) sheet lobes. The vesicles in this flow are small (1-2 cm) and invariably filled with zeolites and other secondary minerals like calcite. The brace of individual lava unites are marked by pipe-amygdales.

A rectangular pit dug towards the south-central part exposed a weathering profile typical of compound phoebe flows (Fig.5). An intricate geometry of lava lobes and toes are seen on the eastern face of this pit are completely vesicular and can be classified as s-type lobes. The southern face exposes three distinct lava lobes. The upper lobe is partially exposed and has developed a crude wreathing profile. The middle lobe is intact and is auger shaped and has a length of 1 m and thickness of 0.5 m. It consists of the typical 3-tiered internal structure of crust–core basal zone but is characterized by the lack of pipe vesicles in the basal vesicular zones. Thus, this relative large lava lobe also belongs to the s-type lobes. The crust of this lobe is highly vesicular and at places develops a crude vesicle banding. The vesicles are small towards the chilled margins of the lobes but become larger (up to 2cm) toward the mid central part of the lobe. A large 0.4 m central gas blister or cavity is seen towards mid central part of lobe. It is typically dome shaped and is lined by zeolites. The western face exposes a chaotic assemblage of small lava toes and lobes. The inter-lobe spaces are highly weathered and show beautiful zeolite mineralization.

3.1 Geo-physical and soil survey

The site of the institute is a basaltic subdued plateau having an elevation ranging from 565 to 547 m with slope being towards south. Geo-morphologically the landscape is divided into summit with side and back slopes. Over the years, the radial drainage has led to gully formation in north-west and north-east of the landscape and creation of severe stony surface cover because of head ward erosion. The natural features of ground associated in nose slope part are gullies where as there is sparse scrub/grass cover on weathering front or soft sheet with rock out crops (> 40% surface cover) on the other parts. The excavation for the *murrum* in one-third of the eastern part had created breakup slope of convex and concave pattern. Since the south east part was under quarry, its landscape was totally distributed. The summit and back slope were associated with 1-3% slope and slide slope and shoulder slope up to 5-10 %.

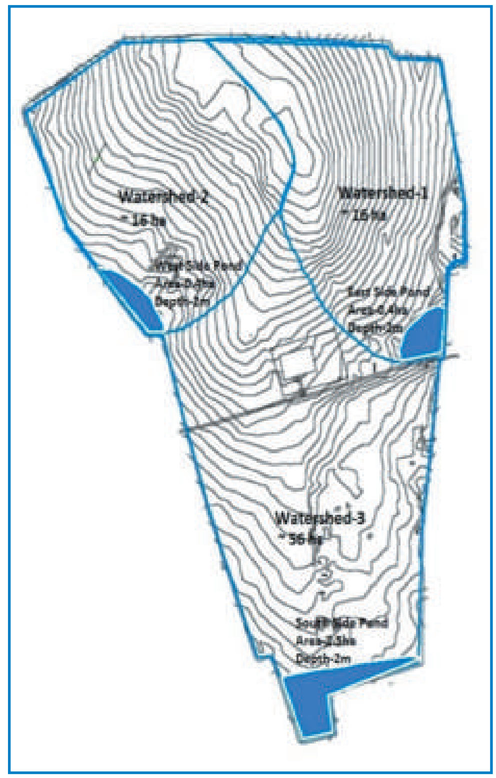


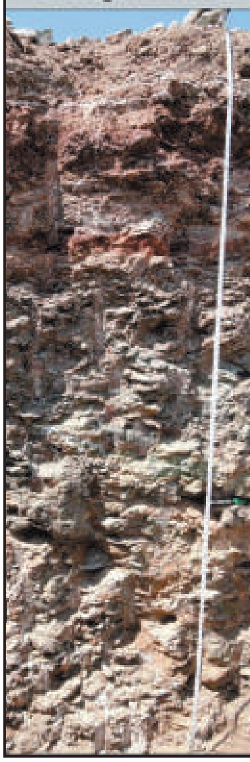
Fig. 3. Google image (Feb, 2009) and contour map based on station survey of institute site

The regular dry spells combined with shallow and gravelly rhizosphere exposes the plants to experience moisture stress. The underlying hard rock and its wavy nature also lead to temporary water stagnation and thus waterlogging stresses. Even the secondary minerals zeolites in the vesicular trap are prone to alterations and release of calcium. The high calcium combined with high pH often results in limited availability of secondary and micronutrients especially the deficiencies of P, Zn, Fe and B are very common.

The soil formation is through the weathering of basaltic igneous rock. The scanty rainfall, recurring droughts, ill drained soil and improper technology for agriculture, ground water recession in addition to high temperature are the major driving forces for the poorly developed soil formation in these areas (Fig.4). The site was covered with shallow 0.1–0.3 m *murrum* soil made with parental basaltic rock shield exposed due to slow physical, chemical and biological weathering process. Soil surveys were conducted for various morphological characters and the observations on a representative profile are presented in Figure 5.

Fig. 4. Some views of the initial barren site

This contained 9 horizons of vesicular flows with varying thickness down to depth of 2.5 m. The overall thickness of surface soil was variable and transported below this layer is weathered vesicular basalt with discrete zeolite and zeolitic vein. Successive layer is the alternate red boll horizon of a variable thickness with fine grained zeolitic intercalation. Intervening horizon between the two red boll i.e. altered vesicular basalt with pockets of clay intercalation is free of zeolite. This is followed by highly fractured/altered vesicular basalt with zeolite crystals. These horizons also show peculiar solution cavities filled up with clay particle or hydrothermal/secondary mineral crystallization zeolite and are the important site for consideration during geotechnical investigation. The lower most horizons are again fractured rock with presence of zeolite veins and therefore presence and absence of zeolite in whole profile section is an important bearing on edaphic stresses on overlying soils.



Geological Profile	Depth (cm)	Horizon	Description
	00		Soil Horizon
	17		Highly weathered vesicular basalt with zeolitic vein
	27		Red Bolls horizon with fine grained zeolitic intercalations
	50		Altered vesicular basalt with pockets of clay intercalations
	65		Red Bolls horizon with intercalations of zeolitic material
	70		Highly fractured vesicular basalt with zeolite crystals
	83		Altered vesicular basalt with zeolite
	113		Altered vesicular basalt
	156		Altered vesicular basalt with zeolite veins
	231		

Fig. 5. A geological log of main pit in cenral part of the NIASM site

3.2 Geo-hydrological Survey

Due to adverse physiographic and geo-hydrological conditions, there are little chances of the occurrence and availability of ground water in the area. The basaltic lava flows with a number of units and impervious top sections constitute poor aquifers. The near surface, highly weathered vesicular zeolitic unit and the under lying moderately weathered, jointed massive unit constitute the main water yielding zone. There are no ground water structures in the vicinity of the institute except for a couple of drinking water bore wells. Electrical Resistivity Method (ERM) was employed to conduct geo-hydrological survey and the delineation of potential/ suitable/ favourable zones for sinking of water abstraction structures for water supply to farm land, plots and other utilities on the campus. The most of the area of the institute was rendered unsuitable for any groundwater. The subsoil strata along the periphery of the site boundary of 3.6 km to a depth of 100-150 cm were also surveyed to know the nature of exposure and their orientation, geo-morphological/topographical and structural control, likely mineralogical make up, development of weathering profiles and relation with soil. A site in the south-west corner was identified for a low yielding bore well to meet the urgent needs of groundwater for drinking purpose but this would need augmentation by inducing recharge towards its catchment through trenched and recharged pits. Hydro-geochemistry of water samples as well as geochemistry of rock/soil samples at different intervals of depth were determined for locating the abiotic stresses. The groundwater of the area is alkaline (pH 7.6 to 8.6) and marginally saline. Total hardness is below the prescribed limit for drinking water. The chloride content is variable (28 to 227 mg/l), nitrate are low (3.2 to 10.5 mg/l), sulphate varies from 70.45 to 72.9 mg/l while carbonate is between 0 to 12 mg/l. The sodium absorption ratio (SAR) is quite low (1.2 to 3.1)

4. Development of Research Farm

4.1 Schematic layout of Farm

The master plan of the institute envisaged a "Model Research Farm" spread over an area of 41 ha for demonstrating soil and water conservation technologies suited to the semi-arid climate of the region. The Google imagery (2009) of the institute site i.e. before the initiation of developmental activities (Fig. 3) depicts that its land was lying as a barren patch as distinguished from the surrounding green agricultural fields. It was predominantly a rocky hilltop without any vegetation. The area has a trapezoidal shape with 1000 m height, and base lengths of 800 m on the north and 300 m on the south. The centrally running, 3 m wide, 500 m long east-west road divided the site into two smaller trapezoids. The north side had few creeks indicating natural drainage pattern of the area and the slope. The south side had a centrally running north-south trail and a dissected patch of a terrain due to intensive excavations for *murrum* and stones. There was hardly any soil on the surface and thus to develop an agricultural research farm on such land presented a huge challenge.

The development works started with planning and designing the farm for which total station survey was done over a 5m x 5m grid to delineate topographic features such as roads and boundary. Based on this, a contour map of the surveyed area was generated with the level difference of 0.5 m (Fig. 3). This indicated that the site forms part of hillock with a presence of few natural drainage creeks, ponds and manmade ditches. The land has an undulating hilly topography with a general slope of up to 4% dropping on three sides (East, West and South) from the highest contour line (108 m) close to the central north boundary of the site. The land has relatively steeper slopes towards east from the central peak while it is sloping gently towards south with slope of less than 2%. The level difference between highest and the lowest point is 17 m. Some isolated non-uniform constricted patches in the contour line pattern indicate the presence of streams and ditches those were mainly generated due to excavations by people for *murrum* before the land was handed over to the institute.

On the whole, the institute also sits on the north ridge line of a major watershed around Nira River near Malegaon, Baramati. Although, an area of 56 ha is too small to apply watershed concept, still, for the purpose of designing water harvesting ponds, it can be divided into three tiny watersheds based on the grid survey and contour map of the land. The whole area may be construed as one watershed enclosed by the boundary wall as a non-natural ridge line allowing all the surface runoff water to be conveyed along its side into the south-side pond. Within this relatively larger watershed, two smaller watersheds can be delineated as shown in the figure 3.

With consistent efforts during the past about three years, the institute has been able to convert the original barren site into a “Model Research Farm” on about 41 ha of its land based on its topography and land capability. The development plan of research farm was designed based on scientific considerations like watersheds, natural drainage pattern, topography, contour map and layout of various buildings in the approved master plan of the institute. The research farm is divided by existing east-west road into south side and north side farms. The actual research plots/terraces in south side farm are spread over a total area of 16 ha while the north-east and north-west farms these occupies an area of 11 and 4 ha, respectively. A chronicle sequence of various activities undertaken to develop the research farm are detailed below.

4.2 South-side Farm

The south-side farm has been planned to undertake research activities related to impacts of abiotic stresses on crop production, livestock and fisheries and their mitigation strategies. This farm is spread over an area of 16 ha bound by peripheral road on three sides and separated from the north side farm by a central east west road. The land is generally sloping from north to south with a gentle slope of less than 2%. Due to excavations of *murrum*, the terrain has a dissected appearance, which is evident from the haphazardly running contour lines (Fig. 3). Considering the area being a part of rain deficit/shadow zone, having no underground water and with only limited irrigation supplies from the adjoining Nira canal, the layout of the south farm was designed on the basis of the considerations of contours for soil and water conservation. While finalising the layout, following concerns were kept in mind:

- Since the plots are to be used for experimental purposes, the uniformity within each should be ensured
- To minimize the costly cutting and levelling activity, the area was divided into plots based on contour lines
- The plot size should be large enough for mechanization i.e. for using tractor drawn implements and small enough for better control over management practices while conducting field experiments.
- Research plots should preferably be square or rectangular to enable straight row or bed planting in lines and also in multiples of standard measurement units like acre or hectare.
- Every plot should have a farm path for easy access and movement of machine and materials as well as layout of irrigation and drainage network. Farm paths can also be utilized for open utility spaces for various post-harvest operations like threshing, winnowing, etc.

Considering the above points, it was decided to create 32 research plots (Fig. 6). Central plots have regular rectangular shape whereas peripheral plots have trapezoidal or triangular shape constrained by the boundary wall. Central square shaped plots have roughly an area of 0.50 ha (68.5 m x 72.5 m). There are farm paths running all around these plots. Some plots, especially those on the west side with steep slope as indicated by closeness of contour lines and those filled up with black soil, were further bifurcated (68.5m x 36.5m; ~0.25 ha) by a field bund in order to reduce cost of filling/levelling. Thus the total number of research plots so generated in five longitudinal blocks now equal 37.

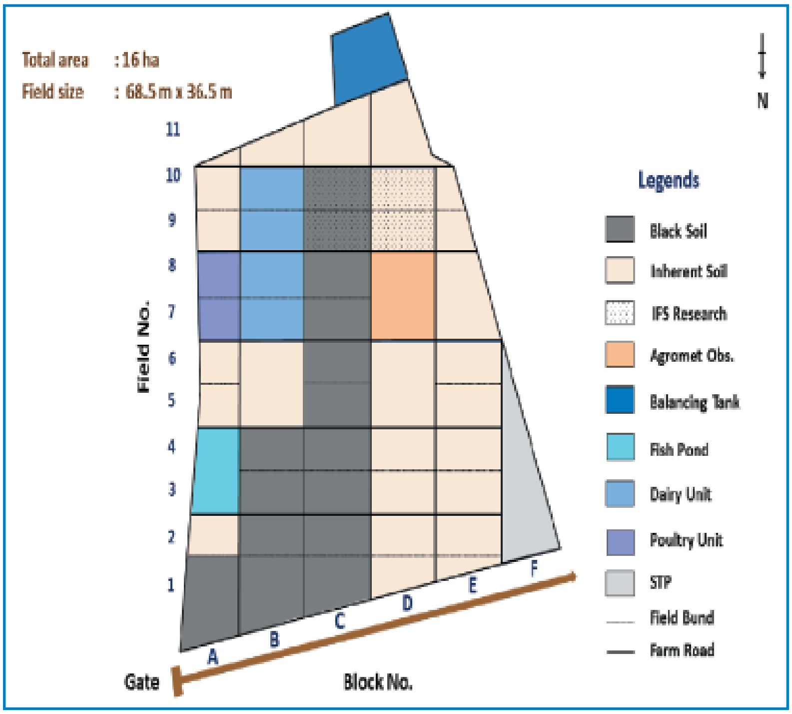


Fig. 6. Layout plan of the south side farm

4.2.1 Disintegration of murrum and basaltic rock

As indicated above that the site was a barren basaltic rocky terrain with soil depth that seldom exceeded 0.3 m and underlying by *murrum* especially in south-farm and hard rock in the north-side. Therefore to hasten the pace of disintegration and soil development, the principle of physical (mechanical) along with chemical weathering processes were adopted systematically. These are briefed as follows:

Step 1: Ripping and chaining

In mechanical process, parental rock blocks were targeted to be disintegrated into smaller sized boulder/garvels/granular forms either by blasting or ripping. Before performing ripping operations using heavy machines (Dozzers, 200 HP), entire north (36 ha) and south (18 ha) side land were subdivided into terraces and subplots based on the topography across the slopes. The elevation difference for levelling of each terrace/subplot was measured by performing the total station grid survey (15 m × 15 m) using dumpy level. The top 0.1 to 0.3 m *murrum* soil was scrapped and separately collected by front dozer before levelling terrace/plots with the aim of reusing this soil for top filling of terrace/subplot. Thereafter, the ripping of the area was carried out using Dozer with ripper (Model No. D355) machine from the Mechanical Division, Irrigation Department, Govt. of Maharashtra for breaking the weathered and non-weathered rock/*murrum* fragments down to the depth which its tines (0.9 m) could penetrate (Fig.7). Finer grades of the primary and secondary zeolite materials were further induced through chaining with the same dozers. The processes of ripping, chaining and pushing were repeated 2-3 times till the terrace/plots got uniformly levelled. Though after each ripping operation, big hardy stones got crushed by chaining with the dozers, the hard stones remaining even after chaining were collected physically and transported for their utilization in filling the base of the roads.

Step 2: Micro-blasting

The hard rocky portions left in patches after chaining and ripping by the heavy dozers were shattered by micro-blasting (Fig.8). For this purpose series of holes of approximately 50 mm size were drilled using semi-automated tractor operated drill machine at spacing 0.5-1 m and 0.6-0.9 m depth depending upon the hardness of the rock along a line defining where the rock should split. Then detonating cords, a flexible tubes containing a centre core of high-velocity, electric cap-sensitive nitrate explosive used as blasting material were inserted into the holes. With proper electrical and blasting circuit, these cords were connected perpendicular together to single current source at a safe location from the blast area. The generator blasting machines type exploder consist of a small, hand-driven electric generator was used for firing of electrical cap. When activated, it produces a direct current

Surface Scrapping

Ripping/chaining of rocky surface

Removal and collection of the heavy boulder for road filling

Second ripping and chaining operation

Levelled, ripped and chained field

Fig. 7. Ripping, chaining, boulder removal and levelling of the site for farm development

pulse that fires the electric blasting caps. The generator connects to the blasting circuit when the blaster pushes down the handle. The low to high initiation impulse ranged from 1.5-2500 mJ/ohm and corresponding current 1.5-35 A were used for blasting depending upon nature of hard rock. Blasting releases energy in the form of fragmentation and displacement of rock, vibration of ground and air blast. The rock cracked during the blasting were collected and used for road filling. The remaining material thus generated was again chained, ripped and pushed for levelling.

Microblasting

Stones afters microblasting

Collection of stones for road filling

Fig. 8. Blasting and boulder removal

Step 3: Application of Spent wash

The sugarcane is the major crop of this region and distillery spent wash, a by-product from sugar industries is available in large quantities. Since the raw spent wash is acidic and having pH 4.0, it was used for reaction with parental rocky materials/*murrum* and thus augmenting the process of soil development by chemical disintegration. Moreover, being a rich source of organic matter (OC 43.8 g/l) in addition to macro-and micro-nutrients (Table 2), it helps the microbes to flourish and induces the reactions of their by-products e.g. organic acids with zeolites and other materials and subsequently resulting in their dissolution. About 24 million litres of raw spent wash (acidic nature) from Malegaon Corporative sugar factory was applied two times with an interval of 6-12 months in all the farm terraces/fields in furrows or on beds with effluent pipes from tankers. The impacts of acids in spent wash and those generated with decomposition of organic matter could be visualised in terms of resultant smaller sized stones/*murrum* so generated (Fig.9). The rocky basaltic/zeolitic boulders/ stones also got so softened and vulnerable after treatment with spent wash that these further disintegrated into smaller pieces of sand and gravels of different sizes when the fields were later ploughed. Thereafter, these fields were fine levelled using tractors with front dozers. Wheresoever needed, the portions of these plots were again ripped using dozers to break the exposed portions of the bed rock. But the spent wash was very effective in weathering the zeolites and *murrum* and improving the overall fertility (organic carbon and nutrients) of the virgin soil. The hard boulders which were not even weathered by spent wash were physically removed from the fields each time these were ploughed and within two and half a year the fields were ready for cultivation with adequate quality of rooting medium i.e. soil.

Table 2. Chemical characteristics of raw and post-methaneted spent wash

Particulars	Raw spent wash	Post-methaneted spent wash
pH	3.8	7.86
EC (dS/m)	30.12	22.3
Total solids (mg/l)	109742	59589
Total suspended solids (mg/l)	34560	11800
Total dissolved solids (mg/l)	75182	47789
Organic carbon (g/l)	43.8	24.6
Total N (mg/l)	2250	1582
Total P (mg/l)	87.5	60
Total K (mg/l)	10840	8420
Total Ca (mg/l)	2730	1850
Total Mg (mg/l)	2100	1536
Total Na (mg/l)	1220	970

4.2.2 Levelling of fields

Land levelling is a precursor to good agronomic, soil, and crop management practices. Uneven soil surface has a major impact on the germination, stand, and yield of crops due to inhomogeneous water distribution and soil moisture. Effective land levelling optimizes water-use, improves crop establishment, reduces the irrigation time and the effort required to manage the crop. In this context top uneven *murrum* surface of the farm plots prepared after ripping, chaining and rough leveling operation done by heavy dozer was fine levelled using tractor operated front dozer (75 HP). For economic development of graded/plane surface, each plot was divided to sub-plots by performing grid survey of 15m x 15 m to find out the centroid. Thereafter average elevation of all sub-plots was determined so that plane passing through the centroid at this elevation will produce equal volumes of cut and fill. Recommended safe limit of the slope

Application of spent wash

Microbial activity and chemical disintegration

Non disintegrated boulder

Second application of spent wash

Field after third ripping and chaining

Fig. 9. Application of spent wash and its reaction products

0.1 -0.4% based on soil condition in the direction of irrigation was considered for levelling each plot. Accordingly desired cut or fill of each plot was calculated by subtracting the elevation of corresponding grid points from proposed average elevation of the centroid (Fig.10). The cut area are subjected to considerable compaction by earth moving tractor with front dozer and hence the excavated earth volume is less than the calculated volume expressed in terms of shrinkage i.e. cut-fill ratio. For NIASM site it was found in the range of 1.2 to 1.7. The volume of earth work of leveling operation was computed using four-point method. Also direction of the leveling operation was fixed on the basis of cut-fill elevation. After completion of leveling operation, level of the farm plots was checked by filling it by water. Low lying spots were again filled up until uniform leveling was achieved.

Removal of stones before levelling work

Complete rough levelled murum plot

Precision levelling using laser leveller

Levelled plot

Fig. 10 Ploughing and precision laser levelling

4.2.3 Uniformity test and enrichment with organic carbon

Once the field plots in the south-side were ready after ripping/blasting, chaining, spent wash application, removal of boulders and levelling, uniformity test was conducted for each field by growing *Dhaincha* (Fig. 11) and also using it for green manuring and thus add to organic matter, nutrients etc. The overall growth of the *Dhaincha* crop was poor on these virgin soils that recorded only about 7-11 Mg/ha of fresh weight (N-2.06, P-0.18, K-2.09 % on dry wt basis) within a period of 8 to 10 weeks. Of course low soil fertility of the virgin soils was the main reason but inadequate canal water supplies also limited the growth of *Dhiancha* during that period.

First *Dhaincha* crop in black soil

Dhaincha at initial stage on virgin soil

First *Dhaincha* crop in native soil

Second *Dhaincha* crop in native soil

Sweet corn non-experimental field

Wheat non-experimental plot

Fig. 11 Uniformity test by growing Dhaincha crop and other crops

The analysis of surface soils showed that these were still gravelly (70-90 % gravels of various sizes and rest 10-30 % less than 2mm) and low in fertility (organic carbon ~ 0.04% and available N and P ~ 14 and 0.47 kg/ha, respectively). Thus further attempts were made to enrich the soil fertility status through addition of organic manures. It was decided to add 20-25 Mg of FYM per hectare. However, due to scattered dairies and utilisation of FYM by the farmers of the area mainly for sugarcane, the institute could procure only about 340 m^3 of FYM (N, P, K 0.45, 0.19 and 0.42 %; bulk density 0.72 Mg/m^3) even with repeated tendering process. This could cover only a part of the south-farm. Therefore, the alternate sources of organic matter were also probed. A Mushroom Farm located had huge stocks of Spent

Mushroom Substrate (SMS). Based upon the cheaper supplies considering its organic carbon and nutrient content (C:N 30:1, N, P, K 2.35, 0.32, 0.17 %), it was decided to procure SMS. Therefore, 990 m^3 of SMS were added to the rest of the plots (Fig. 12). Thereafter, Dhaincha was again grown on the fields supplied with FYM/SMS and this time the crop performance was better (27-33 Mg/ha) and it was again ploughed in for green manure.

Fig. 12. Spent mushroom substrate application

4.2.4 Development of black soil plots

Since the institute intended to provide for farm facilities to conduct research with varying degree of severity and extent of edaphic stresses in diversified soil types, it was planned to develop specified fields representative of black soils of the area, red soil, river sand, salty soils and others at research farm itself. To start with, initiatives were taken to develop a black soil block due to its easy availability and then search for the representative sites of other soils for the establishment of research stations in future. Keeping this in view, 9 plots out of 32 research plots, covering an area of 2.69 ha, were ripped and levelled after breaking and levelling the bedrock using dozers. These were later filled up by transporting black soil/silt from the adjoining areas (3-19 km). A total of 20,381 m^3 of good quality black soil was transported and about 6000 brass (16,990 m^3) was applied to 9 research plots and the rest was utilised for mixing with original soil/*murrum* dug out of pits for establishing orchards and boundary/ roadside plantations (Fig. 13; Table 3). After filling the plots, these were fine levelled by using tractors with front dozers. These were filled up with water to ensure their levelling and settling. Three plots of black soils were laser levelled by tractor operated laser leveller prior to the conduct of experiments.

Fig. 13 Import, filling and levelling of black soil for prepairing field for field experimentation

Table 3. Features of black soil filled plots

Plot No.	Length (m)	Width (m)	Area (m^2)	Soil depth (m)	Black soil (m^3)	Black soil (Brass)
A-1	63	73.5	4631	0.71	3288	1164
A-2	58	38	2204	0.75	1653	586
B-1	70	57	3990	0.91	3631	1285
B-2	70	38	2660	0.97	2580	914
B-3	70	40	2800	0.92	2576	912
B-4	70	42	2940	0.76	2234	791
C-1	68	38	2584	0.75	1938	686
C-2	68	38	2584	0.60	1550	549
C-10	68	38	2584	0.36	930	330
Total	-	-	26977	-	20381	7217

4.2.5 Initiation of Field Experiments

Dhaincha was also cultivated in the fields filled up with black soil to ensure their uniformity and further settling of soil with irrigation water applied to raise this crop. The plots showing non-uniformity due to unevenness of the surface were again levelled and planted with *Dhaincha*. After identifying the uniform fields, multidisciplinary experiments were initiated both on black and native soils during *kharif* 2012 with testing of genotypes of green gram, soybean and sorghum for drought tolerance (Fig. 13). The experiments in the following *rabi* season included identification of traits and genes associated with drought and heat tolerance in wheat, crop-water production functions and the interactive effects of bio-regulators and soil fertility etc. while experiments on resource conservation technologies with sugarcane and deficit irrigation on vegetables have also been initiated.

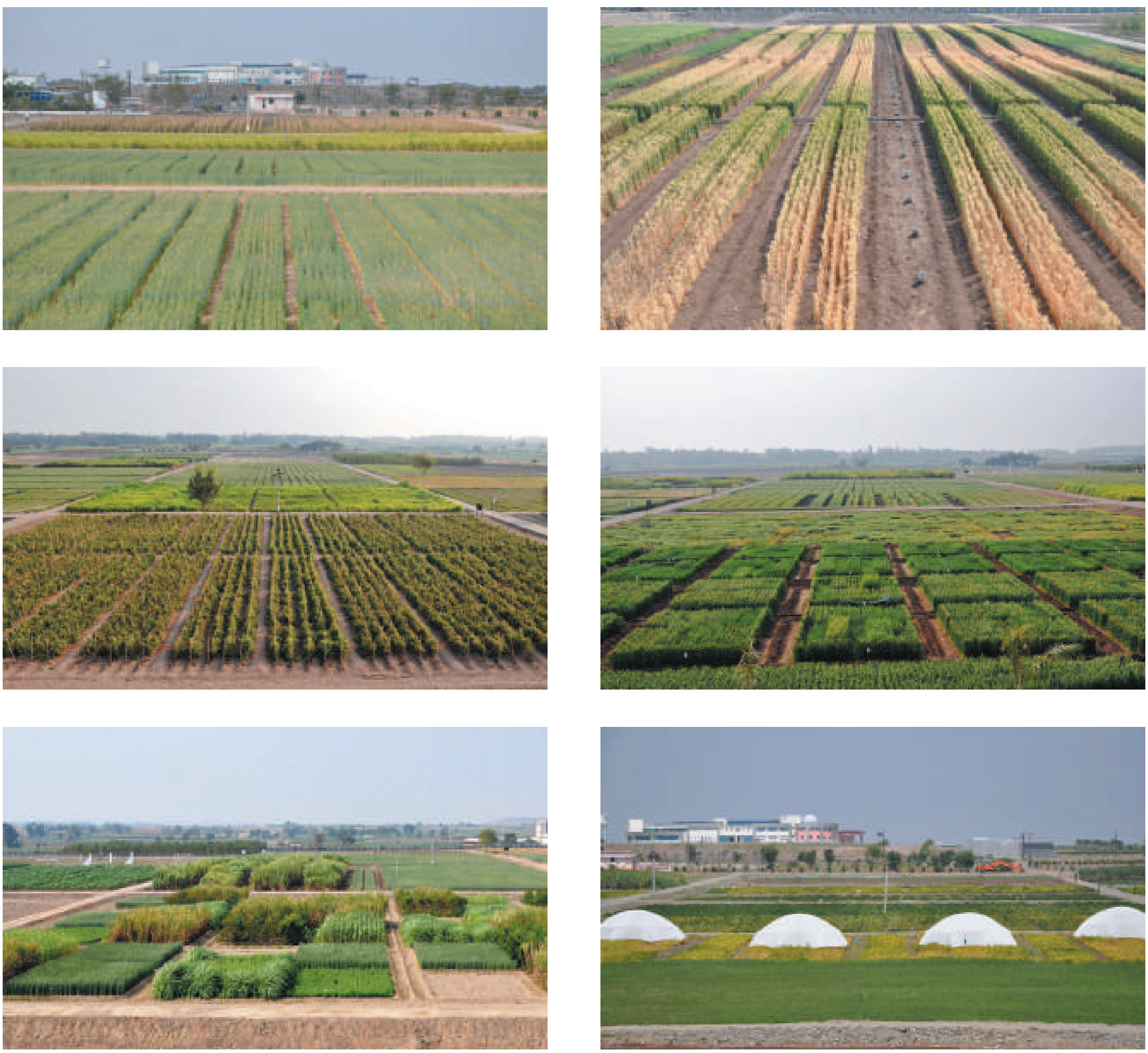


Fig. 13. View of various experiments being conducted on south-side farm

Due to scarcity of irrigation water, the western block of native *murrum*/soil has been put under rainfed grasses/legumes (Fig. 14) like marvel grass (0.25 ha), stylos (0.25 ha) and leucaena (0.5 ha). Besides the production of fodder/fuel, these crops should help in soil development through addition of organic matter and root exudates. A small field has been put under Cactus (fruit/fodder type cultivars) and these are being tested to decipher traits and genes associated with tolerance to drought and edaphic stresses. Either the general crops of wheat, chickpea, soybean, sorghum and maize or *dhaincha* for green manure is being regularly cultivated on rest of the field plots for enhancing their uniformity and organic matter. In addition, 3 small ponds have also been constructed for fisheries research and almost all the fields are now ready for experimentation except around two ha area has been reserved for setting up of an 'Integrated Farming System Model', one ha for livestock/poultry sheds and agro-met observatory has been set on an 0.5 ha area.

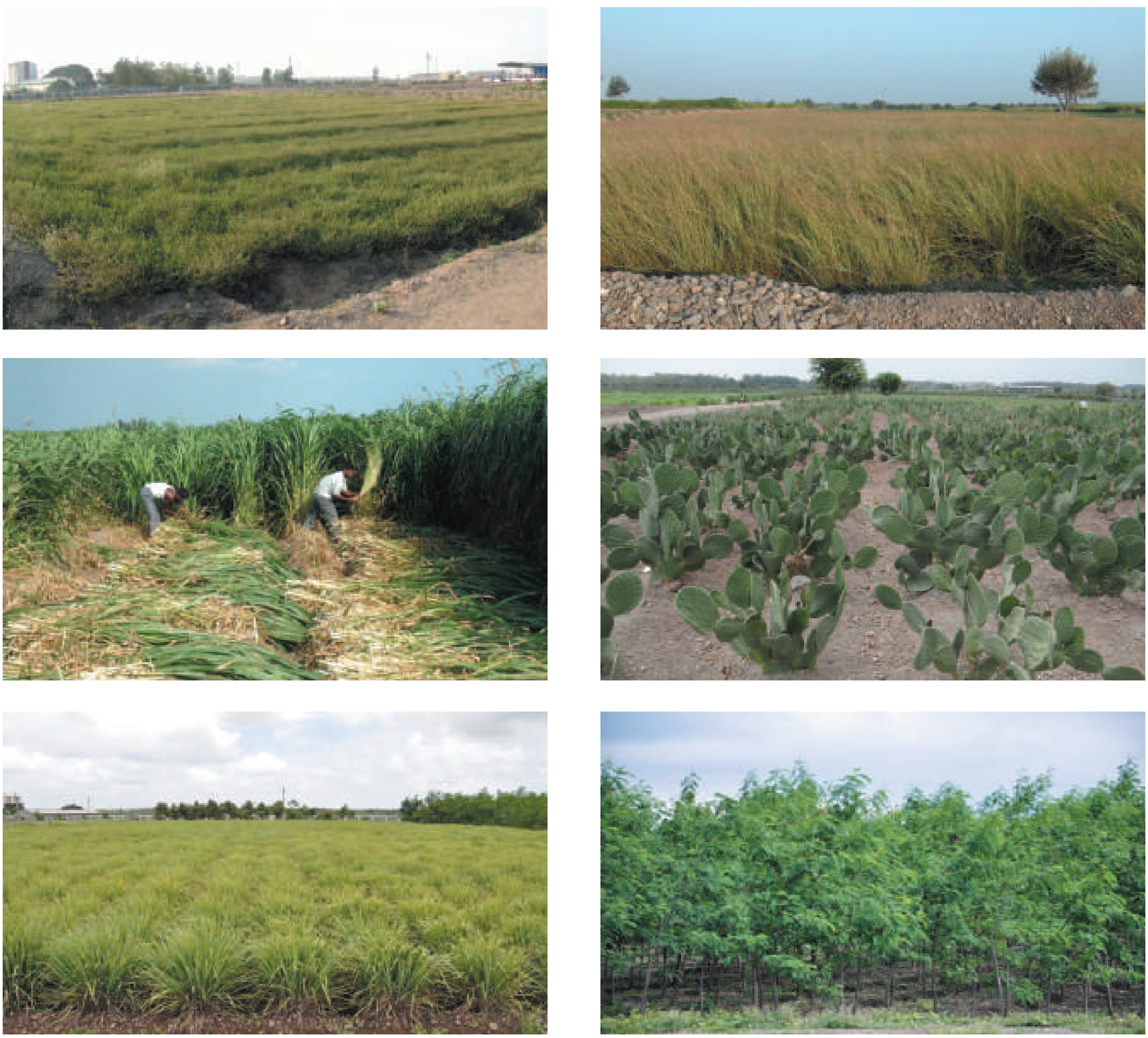


Fig. 14. Alternate land use systems established in virgin soil

4.3 North Side Farms

In Maharashtra, about 10.3 MT of fruits are produced annually and it ranks first in the country especially in the production of low water requiring fruits like grapes, pomegranates and oranges. The other fruits like banana, mango, coconut, sapota, guava and cashew-nuts are also produced to a large extent in the state. About 42% of degraded land mainly suffers with hard pan and having shallow soil depth. Resultant edphic and drought stresses in these lands reduce the longevity and potential yields of orchards especially due to high vulnerability to droughts which occur almost once in three years in 50% area of the state. Multiple nutrient deficiencies are also very common on these basaltic soils. Moreover, the impact of climate change on land degradation has drawn worldwide attention wherein the importance of geological formation has been taken as an important stress parameter to define the quantum of degradations. Therefore, introduction of new crops, innovating management options and identifying tolerant crop/genotypes are options to avoid/ mitigate/ adapt to the edaphic stresses to which the orchards are vulnerable on these lands. Keeping above in view, the north-east and north-west side farm have been dedicated to research on devise planting techniques, the filling mixture for planting sites and the exploring possibilities of deficit irrigation/partial root drying techniques for the profitability and sustainability of orchards on basaltic/*murrum* soils.

4.3.1 North-east side farm

The north-east side farm admeasuring about 8 ha, has about 4 per cent slope towards east and south east. It was decided to convert this into three blocks each having six contour terraced fields of 33-35 cm width and a total of 18 terraced plots were generated. The length of these terraces varies between 90-110 m, 170-200 m and 160-200 m in three blocks depending upon two farm paths passing through each block.

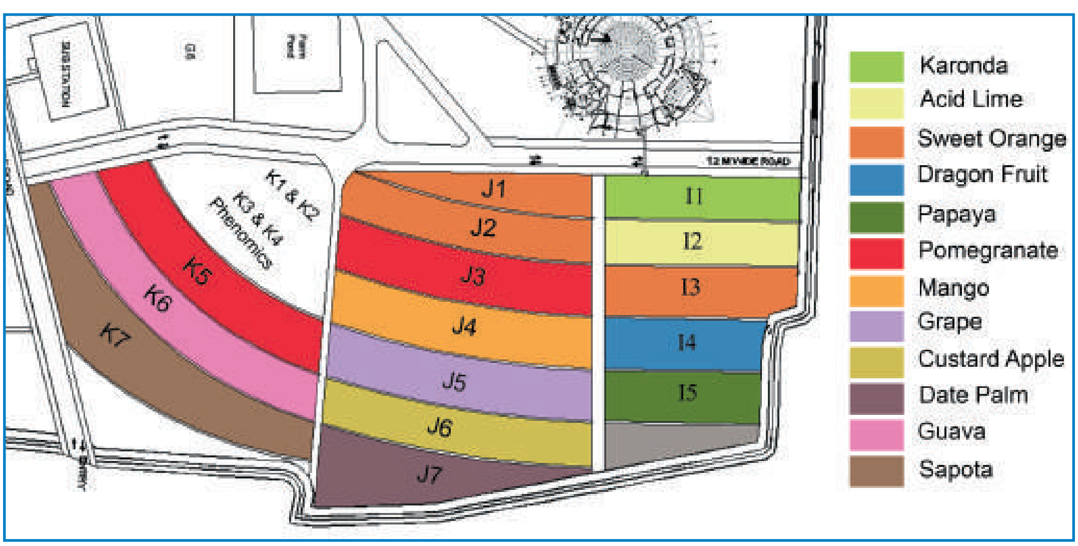


Fig. 15. Layout plan of north-east farm

To minimize cutting and levelling activity using heavy duty ripper-dozers, it was decided that terraces to be generated should have field bunds those follow contour lines. The sequence of steps/processes followed to develop this farm was similar to development of south-side farm. Briefly, these include pushing the surface soil to the lower side to expose the *murrum*/rocky bed, ripping/blasting of the exposed bed and levelling after removing big boulders by using 350 HP Dozer-Ripper for initial coarse work. A 200 HP dozer and 75 HP tractor mounted dozer were used for giving contour shape and making bunds. There after spent wash was added and terraces were left for the reaction to occur. These were again ripped and levelled removing the oversized stones. These have then been put under various orchards as given in table 4.

Table 4. Typical features of orchards established in north-east side farm

Block/Terrace no.	Area (ha)	Orchard planted	Variety	Spacing (m)	Date of transplanting	No of Saplings planted
I1	0.32	Karonda	Konkan Bold	3.0 x 3.5	30/08/2014	280
I2	0.33	Acid lime	Phule Sharbati	4.5 x 5.0	30/10/2013	154
I3	0.35	Sweet orange	Nucellar	4.5 x 5.0	27/08/2013	176
I4	0.33	Dragon fruit	Red Colour	3.5 x 3.0	06/12/2013	330
I5	0.33	Papaya	Red Lady	2.0 x 2.0	19/08/2013	768
J1 and J2	0.80	Sweet orange	Nucellar	4.5 x 5.0	24/09/2014	390
J3	0.60	Pomegranate	Bhagwa	4.5 x 3.0	04/11/2013	420
J4	0.60	Mango*	Kesar	4.0 x 3.0	07/10/2013	480
J5	0.62	Grapes**	Thompson/ Sharad	2.75 x 1.5	10/09/2013	1392
J6	0.62	Custard apple	Hyderabad sel.	4.0 x 4.0	31/05/2014	390
J7	0.39	Date palm	Barhee, Halawi	8.0 x 8.0	12/12/2013	61
K5	0.40	Pomegranate	Bhagwa	4.5 x 3.0	03/07/2013	380
K6	0.54	Guava	L-49	4.5 x 4.0	08/07/2013	300
K7	0.69	Sapota*	Kalipatti	5.0 x 5.5	25/06/2013	250

*Due to severe damage by hailstrom on 9th Mar 2014, sapota was replanted on 21st May; Half the mango saplings were replanted on 25th June.
** Grapes grafted with Dogridge rootstock on 18-19 July 2014

The southern block (K) nearing to main road at entrance has 7 plots of size (0.30-0.69 ha). The topmost and lowermost terraces are dedicated to phenomics facility and for developing a rock garden respectively, while the inner three terraces have been planted with sapota, guava and pomegranate to generate information of planting techniques and filling mixtures (Fig. 16). A unique concept of sub-surface water storage as created by blasting 1.0m rock below the planting site is being tested to reduce vulnerability to droughts and minimise the supplemental irrigation requirements (Fig. 17). Similarly different volumes of rhizo-sphere (auger, pit and trench) have been disturbed for root proliferation of above fruits varying in their rooting patterns.

Fig. 16. Views indicating various steps in development of orchards in north side farm

Fig. 17. A unique sub-soil water conservation technique being tried for sustaining orchards

The middle block (J) is dedicated to orchards having variable tolerance to drought (date palm, custard apple, grapes, mango, pomegranate) and the newer concepts of regulated deficit irrigation (RDI)/partial root-zone drying (PRD) would be tested by providing differential edaphic environments through the use of various filling mixtures/ replacements of dugout soil with various proportions of black soil as well as creating differential demands for hydraulic lift of fruit plants through use of bio-regulators/anti-transpirants etc. Viability for introducing new orchard crops like papaya, dragon fruit, karonda etc. is being tested in the north-most block (I). In addition to standardising the method of planting and filling mixtures, the RDI/PRD would also be tested to minimise the supplemental irrigation requirements for the sustenance of these orchards and those of sweet orange and acid lime.

4.3.2 North-west side farm

About 4 ha of north-west side farm including a water balancing tank (60 m x 60 m x 5 m; 15 ML capacity) and a playground (120 m x 90 m) have been developed into two block having 7 experimental plots with average riser height of 1 m and a run-off water recharging tank in the lowermost western end (Fig.18). The steps followed for their development were the same as enumerated for south-farm. Different orchards (Table 5) have been planted following the same procedures as listed for north-east terraces with the objectives of identifying the suitable planting techniques and filling mixtures to obviate edaphic stresses in orchards grown on shallow basaltic soils and optimising irrigation schedules for drip irrigation in orchards and the role of deficit irrigation/partial root zone drying in orchards; evaluation of the role of high water retentive and fertile black soil in defining water requirement and elucidation of physiological manifestations and drought tolerance in orchards (Fig.19). However, another concept being tested for Nagpur Mandarin is to enlarge rooting medium by pushing the surface soil for creating raised beds of 0.6 m height, 1.5 m surface width and spaced at 4.5 m. The trenches (0.3 m deep) so generated between two beds would be utilised for storing run-off water.

Fig. 18 Layout of orchard crops on north-west side

Table 5. Typical features of orchards established in north-west side farm

Block / plot no.	Plot size	Area (ha)	Orchard /Cultivar	Spacing (m)	Date of transplanting	Total saplings
G-2	96m x 45m	0.43	Aonla cv. NA-10	6.0 x 6.0	11/09/2014	110
G-4*	96m x 45m	0.46	Grapes cv. Cabernet Sauvignon*	2.50 x 1.25	01/07/2014	1470
G-6**	100m x 60m	0.60	Nagpur mandarin **	6.0 x 5.0	30/09/2014	240
H-1& 2	80m x 45m	0.36	Drumstick	3.5 x 3.0		400
H-3	80m x 45m	0.36	Fig cv. Poonafig	4.0 x 4.0	27/08/2014	225
H-4	80m x 45m	0.36	Guava cv. VNR-Bihi-1	4.0 x 4.0	19/07/2014	225
H-5	80m x 48m	0.38	Papaya cv. Red Lady	2.5 x 2.0	07/07/2014	768
	Total area	2.95				

*110R is used as rootstock for grafting in grapes on 19 Oct. 2014;** *Citrus jamberi* is used as rootstock for budding in Nagpur mandarin

Fig. 19. Orchards established in NW farm

5. Peripheral and Avenue Plantations

Keeping in view the limited supplies of irrigation water and the suitability to the climate, it was decided that only those plantations would be taken along the boundary which would have ornamental value as well as generate revenue for the institute (Table 6). Accordingly coconut was selected for its wide spacing, suitability to both edaphic and climatic conditions and for its year round revenue generation (Fig.20). A tall coconut variety (Banawali (WCT)) was planted all along the boundary with the plant to plant spacing of 9 m. Before planting, pits (1x1x1 m^3) were dug using excavator machine, another 1 m depth of hard pan was loosened using breaker to facilitate better root penetration/development for coconut. Breaking of hard layer was carried out even in the top 1 m due to the presence of hard stones and boulders in all the pits. These were filled up with mixture of 1:1:1 of parent soil:

Fig. 20. Views of various steps in boundary plantation of coconut

black soil and Spent Mushroom Substrate (SMS). Other cultural practices were followed as recommended.

For planting trees along the inner side of the peripheral road, one thousand pits (1x1x1 m^3) were dug using poclain and JCB machines. These pits were filled up with black soil and farm yard manure in 3: 1 proportion along with fertilizers. Fruit plants like sapota, jamun, ramphal, bael, sitaphal, aonla , tamarind, teak and dwarf coconut were transplanted keeping the spacing of 6m between saplings. Bael was planted between teaks which were planted in the northern side of periphery to give better shade in avenue besides good returns.

Similar criterion was also followed for plantation of ornamental trees/shrubs along the main roads (12m) adjoining main entrance to office-cum-admin block (650 m) and that to the back entrance gate (300 m). Two-tier plantations have been taken, keeping rows of bottle palm spaced 8 m between plants on either sides of the road and Ficus planted on inner row to palm (Fig. 21). This pattern was followed from main gate to first crossing towards the main building, while the outer row has been replaced with Terminalia and the inner row with Bougainvillea, respectively for the patch between road crossings to boundary wall behind the admin. block. Only a row of Jack fruit saplings has been planted along the rest of main road until the back entrance gate. Along the road running in front of admin block towards boundary wall, a row fox tail palm was planted on both sides with spacing of 7 m between plants.

Table 6. Plantations along boundary wall and roads

Common name	Botanical name	Spacing (m)	Total no. of plants
Coconut	*Cocus nusifera*	9	405
Foxtail palm	*Wodyetia bifurcata*	6	100
Bottle palm	*Hyophorbela genicaulis*	8	50
Jamun	*Syzisiumcumini*	6	72
Bael	*Aegle marmelos*	6	130
Jack fruit	*Artocarpus heterophyllus*	8	60
Aonla	*Emblica officinalis*	6	37
Tamarind	*Tamarindus indica*	6	40
Terminalea	*Terminallia mentalis*	8	144
Booganbel	*Bougain villea*	8	134
Teak	*Tectona grandis*	6	47
Ficus	*Ficus bengalensis*	6	62
Wood apple	*Feronia limonia*	6	70
		Total	1356

Fig. 21. Development of roadside plantations

6. Irrigation and Drainage Networks development

6.1 Irrigation Network

The only source of irrigation water for the institute research farm is Nira canal, which is flowing at a distance of 500 m from south end of the institute. The elevation difference from canal base to institute top is 26 m. The institute plans to cover the whole farm and landscape (~50 ha) with auto-irrigation and that too through drip/sprinkler systems. For this, institute has obtained permission from Irrigation Department, Govt. of Maharashtra for drawing water from Nira canal through a Lift Irrigation System (LIS) by installing 2 x 50 HP pump sets. Two water balancing tanks have been planned along with a pump house for the north side as well as south side farms. Irrigation Department has also granted special permission for a sump well/use of an earlier abandoned well and pump house along the Nira canal. However, the institute was earlier accorded permission for LIS for drawing water by installing 2 x 25 HP pump sets. Since the PVC pipeline installed for conveying water from Nira canal to institute is having only 140 mm diameter, a 20 HP mono block pump set having 22 lps discharge has been put at the canal site and this is equipped with GSM based mobile system for remote operation. Since the present water supplies meet the the water requirements of only about 8-10 acres, the irrigation network was initially planned for the south side farm (Fig. 22). The PVC pipe of 140 mm and 90 mm diameter was laid along the plots and farm paths. Each plot size of 0.25 ha is provided with one outlet which is then irrigated through either sprinklers or furrows connected to sub-plots/experimental plots.

Fig. 22. Installation of irrigation system in the south farm

Since all the terraces/ plots in the north-east and north-west side have been planted with orchards, irrigation network with pressurized irrigation systems i.e. drip irrigation system was designed to minimise the conveyance losses. The present layout of the irrigation network for these orchard crops comprise of the 90 mm PVC pipe as main pipe, 63 mm PVC pipe as sub main and 16 mm LDPE laterals (Fig.23).

Fig. 23. Installation of drip irrigation system in north-east farm

6.2 Drainage Network

The NIASM site being placed at an elevated site and having soils made of *murrum* derived from hard basaltic rock, drainage is not a problem *per se*. However, shallow soil depth over the hard rock pan leads to water ponding and runoff problems especially during extreme events of high intensity precipitation. Considering these facts, all terraces and plots were leveled maintaining grade of 0.1-0.2% towards downstream side to let excess water gravity flow along the farm paths in open ditches. Accordingly, open surface earthen drainage ditches (0.15- 0.2% grade) of requisite capacity were excavated alongside farm paths as sub-drains (Fig. 24). Furthermore, these sub drains carried the excess water to nearest storage pond through main drain line. For the design of drains, various parameters such as velocity of run-off water, discharge rate and bed depth were considered to prevent any scouring of farm paths as well as plots. Cement pipes of 150-450 mm diameter were laid for crossing paths and bunds wherever required. Semi-circular earthen drainage ditch of 0.5-1.0 m top width and 0.3-0.5 m depth was constructed inside peripheral boundary road to collect all the runoff water to the three water harvesting ponds on three sides of the land.

Runoff water channeled to the depression area (north-west side)

Fig. 24. Drainage network and runoff water collection sites

7. Farm Road Development

As per the master plan, the design dimensions of the concrete/bitumen roads consists of; i) 12m wide main road of a) 480 m length connecting main entrance gate in the east and the small gate in the west and b) 570 m road connecting the above east-west road to administrative building upto northern boundary wall ii) 9m wide roads between admn. block and central laboratory (235 m), from central laboratory to guest house (320 m) and a cross road to this up to western boundary wall passing via type-IV quarters (270 m), and iii) approx. 3.5 km peripheral boundary wall road of 3-4 m width.

The entire south side farm has been divided into six main blocks in north-south direction by five main paths (3.5m) while the central path being 4.5 m wide. For easy farm operations and accessibility, south farm is again sub-divided by five cross paths of 3m width. Thus, this farm has been divided into a total of 37 research plots. Of these, centrally located 32 research plots are of regular rectangular shape of size 68.5 m x 36.5 m measuring 2500 m^2 area each, while the rest are of the size 68.5 m x 72.5 m. For developing farm roads, heavy stones collected after ripping of field plots (Fig 25) were used as bottom layer, channelled and chained using heavy dozer (350 hp) of irrigation department, and then a layer of *murrum* (10-15 cm) was placed on the top. Keeping in view the topography, a uniform slope up to 2% was maintained for preparation of farm roads. The total length of paths in the south side farm is about 3250 m consisting of five north-south paths of 2000 m and six east-west paths crossing the above paths and measuring about 1500 m in length.

The eastern part of the north side farm has been developed by terracing and levelling of 11 ha area with the help of heavy machinery and tractors with front dozer, back hoe loader, breaker etc. The area was divided into seven terraces with width ranging from 35 to 38 m. Two farm paths running east-west across terraces divide the whole farm into 21 plots. The big boulders and stones were placed at the bottom layer of farm paths with 10-15 cm thick *murrum* on the top. These farm paths were further levelled with 3-4% slopes based on the topography of the terraced land. The two paths divide entire eastern part north side farm into three blocks. First farm path of total 200 m length and 8 m width is between northern and the central block while the other farm path of 206 m length and 5 m widths is between central and southern block. After dumping the boulders at the base and *murrum* at the top of the l farm paths, the material was compacted by heavy vibrator type roller for final shaping (Fig. 25).

Similarly, a network of roads in western part of north-side farm is integral part of the administrative, quarters, guest house, club-house, central lab and school building. This part was developed by terracing and levelling of 4 ha area with the same machineries as used in eastern part. The area was divided into four terraces with width ranging from 45 to 48 m. Two farm paths running east-west across terraces and one running north-south along the terrace divide the whole farm into 9 field plots. The big boulders and stones were placed at the bottom layer of these farm paths with 10-15 cm thick *murrum* on the top. These farm paths were further levelled with 4-5% slopes based on the

Initial detopping land marked for farm paths

Dumping of the boulders

Setting of boulders in line for road

Application of murrum

Kacha *murrum* road

Application of fine *murrum*

Pressing of *murrum* layer with road roller

Completed road

Fig. 25. Development of farm paths in south-side farm

topography of the terraced land. The developed farm paths divide entire western part north side farms into two blocks (G & H). First farm path of total 160 m length and 4 m width is between G and H block while the second farm path of 128m length and 3.5 m widths is between G block and eco region. The third farm path of 96 m and 5 m width runs between G3 and G4 plots.

In total 37,913 m^3 (13,387 brass) of boulders and 7612 m^3 (2687 brass) of *murrum* was used for laying both bottom and top layers, respectively for development of all farm paths. The reuse of the boulders not only saved upon their disposal costs but also helped in saving costs that should have been incurred in preparing the base of the institute roads as per the approved master plan. The overall estimates on savings are about approximately 2 crores.

8. Construction of Fish Pond

Since the mandate of the institute includes multidisciplinary and multi-commodity research on abiotic stresses, the livestock, poultry and fisheries units are an integral part of the research farm. Therefore, fisheries ponds at the farm have been designed to develop strategies for mitigating the water scarcity and heat stresses those are most prevalent in the region. The details of specification of these ponds are described as under.

Based on the total station survey, a plot (83m x 50m) in the natural depression was selected with the objective of minimizing the earthwork for construction of dugout fish ponds. This was the location where runoff and irrigation seepage water around the catchment also gets collected. The soil profile contained sufficiently impervious and thick layer material below 0.5 -1 m depth with almost negligible seepage rates. Based on the requirements of fishery section, the initial site of about 4000 m^2 (Fig. 26) was bifurcated into three sub- ponds; i) nursery pond [40 m x 22.5 m x 1.2m], ii) rearing pond [40 m & 41 m (side lengths) x 23.5 m x 1.55 m] and iii) stocking ponds [40 m & 41 m x 57& 53 m x 1.8 m]. Provision exits to further divide the ponds into still smaller ponds. The shape of the pond was kept rectangular for efficient utilization of land, healthy fish growth and easier fish catching operation (Fig. 27). The water depth of 1 - 3 m is generally considered as ideal for fish ponds. The pond shallower than 1m depth often gets overheated and depleted of O_2 during peak summer and affects the survival and growth of fish and other organisms. However, water depth greater than 4 m are rare for fish culture and less productive because of lesser sunlight and water turbidity. The design of fish pond was finalized after collecting data on different design parameters of commercial fish/farm ponds available in Western Maharashtra.

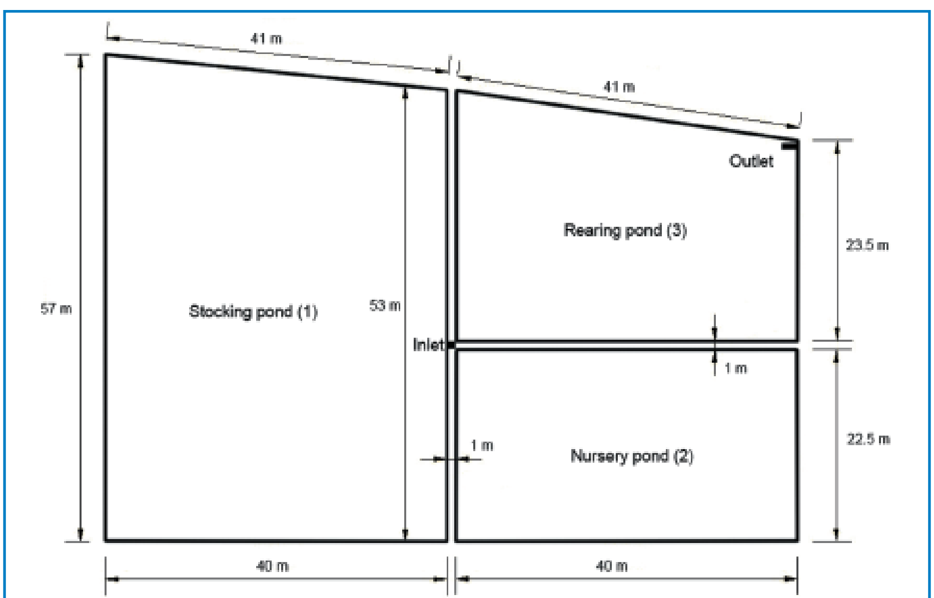


Fig. 26. Design of fisheries ponds

Layer wise excavation

Embankment formation

Levelling of black soil

Cushioning by black soil

HDPE Lining to prvent seepage

Testing for seepage loss and evaporation

Pond ready for fish rearing

Start of experiment with Hapa culture

Fig. 27. Development of ponds for fisheries research

The layout of three rectangular shape fish ponds was prepared keeping in view the land configuration and elevation of the area. The deeper sides of these ponds are positioned in the lower elevation for minimizing the earth-work. The ratio of size and water area of nursery, rearing and stocking ponds depend on the proposed capacity for fish production. For constructing the fish ponds loose *murrum* material of the selected site was initially scrapped using front dozer. The pond site was ripped stepwise for removal of hard rock material till the machine was effective. Thereafter, a series of micro blasts were made to dug out the rock and this continued until the desirable depth was attained. The pond embankments of size (1.2 to 3 bottom depth, 1 m top width and 4 m bottom width) with natural side slope (1:1.5) were constructed using scrapped *murrum* and fine boulders removed after digging of the pond. Additional hard materials remained was crushed by chain dozer and transported as filling materials for the farm path preparation. The grid survey (15 m x 15 m) was performed to measure the pond bed elevation difference for fine levelling. The shaping of the slanting sides and levelling of beds of the ponds was achieved with bucket and breaker poclain machines. Approximately 200 brasses of black soil (15 cm thick bottom layer) was applied uniformly as cushion to avoid the damage of the lining material. The blue colour HDPE sheet (300 GSM) was used as lining material for the all fish ponds. The pond was filled with water and tested for seepage losses if any.

9. Construction of Water Balancing Tank

Taking into cognizance the facts that the crops and orchards under different experiments and the landscaping plantations are to be sustained even during the canal closures/ limited water supplies, two of the balancing tanks have been planned with a total capacity of 30 million litres. The dugout farm pond of 10.50 million litres capacity has been constructed to replace the earlier Agromet observatory site to cater to the water requirement of 16 ha horticultural plantations in the north-east and north-west side farms and 8–10 ha landscape around main administrative building, staff quarters and guest house, schools, hostels etc. The earthen embankment farm pond was constructed on the highest elevated terraced site based on the undulating topography (average slope up to 4%), parental rock structure and source of water for filling the pond. The detail of the design parameters for the earthen embankment type water storage tank was shown in the Fig. 28.

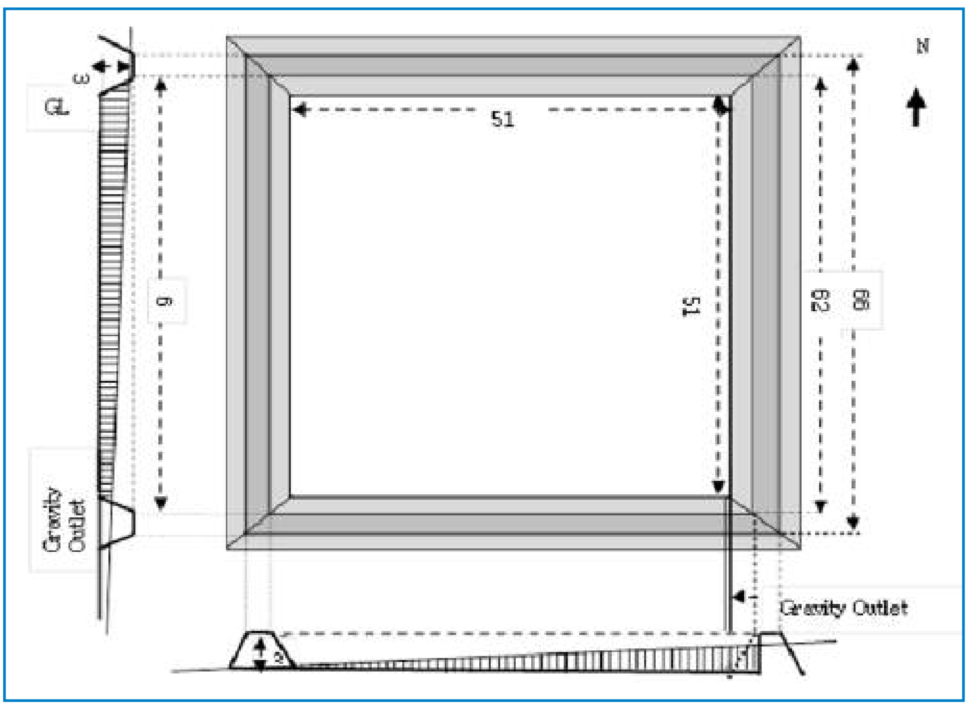


Fig. 28. Design of the water balancing tank in the north side

The square shape storage tank of 66 m top, 51 m bottom sides with 3 m depth was selected to minimize the evaporation losses (30-35 %). The selected site was basically the old observatory site filled with *murrum* soils and stones collected from the nearby areas during the farm development. The site is initially surveyed (15 m x 15 m) to check the level of the table top surface and pond layout was demarcated. About 55% loose materials (577 m^3) like *murrum* soil and loose stones were excavated stepwise through front loader and back hoe bucket dozer (JCB 75 hp) and transported for road and field plot preparation. The remaining 45% parental hard rocks (473 m^3) were removed by the ripping through heavy

Fig. 29. Construction of water balancing tank in northern side

dozer and micro blasting. Unbroken hard rock material was breakdown into smaller size by chaining operation of heavy dozer so that it can be utilised as filling material for the farm road preparation. After achieving the 3 m bottom depth and natural slopes (1:1) bottom floor and slanting sides was fine levelled through the poclain machine (210 HP) with breaker and bucket mechanism. Thereafter about 200 brass of black soil with 15 cm was applied as cushion material before installation of pond lining material i.e. HDPE sheet of 600–1000 GSM size. About 5600 m^2 bottom and side area was covered with HDPE lining sheet material for avoiding the seepage losses. The inlet and gravity outlets each of 15 cm diameter PVC pipe (6 kgf/cm^2) were kept for filing of water into storage pond and removal of the water from the storage pond for irrigation purpose (Fig.29).

Another dugout water balancing tank is planned at the south-end of the farm. Its size is 60m x 60m and 5m deep. Method of its construction is same as described for the other tank as above except it will be lined with concrete. This tank will be used for initial storage of water as pumped from the canal. Thereafter, the water will be used for irrigation of experimental plots in the south farm, plantations along the south-boundary and also for pumping of water to the upper water storage tank for its use in orchards and landscape in the north.

Visit of dignitaries during farm development journey

Secretary, DARE & DG, ICAR, Dr. S. Ayyappan

The then Union Minister of Agriculture Sh. Sharadchandraji Pawar

Secretary, DARE & DG, ICAR, Dr. S. Ayyappan

RAC members

Agriculture Commissioner, Govt. of Maharashtra

Dr R.K. Gupta, CIMMYT

Dr. S.K. Chaudhari, ADG (SWM)

IMC members

Directors of ICAR and VC's of SAU's during 2014

Trainees of Winter School MPKV Rahuri

Machineries used for development of the farm

Dozer with rock ripper

Excavator with bucket

Excavator with rock breaker

Front and back hoe loader

Tractor with front dozer

Road roller with vibrator

Tipping Trolley

Rotavator

Rocks excavated during farm development

Rhombodhedral Calcite and Stilbite

Mordenite, Stilbite and Heulandite

Stilbite and Apophyllite

Stilbite

Heulandite

Calcrete

Apophyllite and Stilbite

Zeolite

Hydrothermally altered Basalt

Making of Roads

Development of road from East to West entrance gate


Expansion of East West Road


Digging of trench


Stone filling

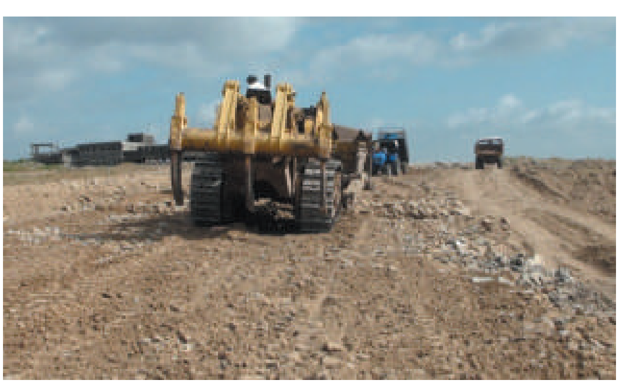

Application of *murrum* and completed East-West road

Development of road approaching main admin. building from East-West road




Dumping and filling with boulders






Application of *murrum* and completion of road work

Development of internal roads in the North-West side of research farm

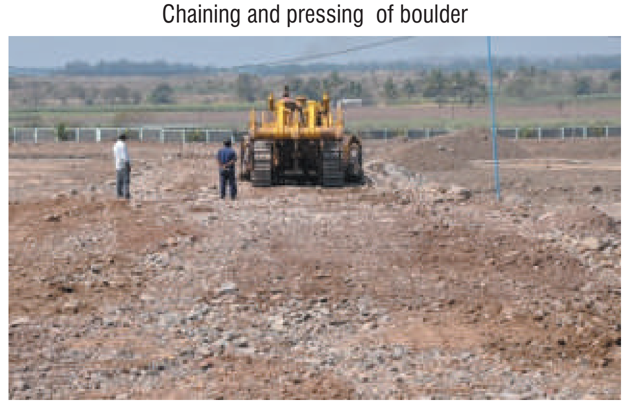
Road layout of north west side

Scraping of *murrum* and road demarcation

Dumping and filling with boulder

Chaining and pressing of boulder

Road after first chaining by dozer



Second chaining

Application of top *murrum* layer

Developed road

Orchard development in North-West side farm

Bhoomi puja

Planting by Hon'ble Scty DARE & DG, ICAR

Aonla (G3)

Initial ripping in aonla field

Blasting

Field levelling

Pit making

Grape (G4)

Blasting

Ripping after blasting

Trench making

Grape orchard

Nagpur Mandarin (G6)

Raised bed formation using JCB and poclain

Levelling trenches between raised broad beds

Adding black soil & planting of Nagpur mandarin

Fig (H3)

Opening field for blasting

Fig orchard

Guava (H4)

Settling bunds using poclain

Making pits using JCB

Making pits

Guava orchard

Papaya (H5)

Microbalsting

Removal of boulders

Auger hole making

Papaya orchard

Orchard development in North-East side farm

Karonda (I1)

Field preparation

Karonda plantation

Acid lime (I2)

Acid lime planting

Acid lime orchard

Sweet orange (I3)

Preparation of field

Sweet orange orchard

Dragon fruit (I4)

Making trenches

View of dragon fruit orchard

Papaya (I5)

Making pits

Papaya plantation

Sweet orange (J1 & J2)

Creating bunds using boulders from field

Making pits using poclain

JCB to remove boulders

Sweet orange orchard

Pomegranate (J3)

Making pits

Pomegrante planting

Irrigation

Training with multiple stem system

Mango (J4)

Making pits

SMS application

Mango planting

Field view

Grape (J5)

Making trenches

Application of black soil

Erecting Y trellises

Crop after grafting

Custard apple (J6)

Initial field

Custard apple planting

Datepalm (J7)

Planting

Datepalm orchard

Pomegrante (K5)

Making pits

Field view

Guava (K6)

Removal of boulders

Field view

Sapota (K7)

Making trenches

Sapota orchard

Satellite imageries of NIASM (Courtesy Google map)

2007

2012

2014

Aerial view of NIASM Farm

2012

2014

Then and Now... transformation through lens

Then (2010)	Now (2014)
	
	
	

South farm

Comparative bird eye view of NIASM

2012	2014


Southern side


North-West side


North-East side

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

राअप्रस
NIASM

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