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Revisiting the agro-ecological zones for crop evaluation

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Abstract

Food and nutritional security on sustainable basis are the major challenges of the 21st Century. The domestic production needs to be increased @2% for cereals and pulses and 0.6% per annum for oilseed to meet the projected demand by the year 2030. The speed of the expansion of irrigation potential of 140 m ha is very tardy at present. Irrigation has been possible in only 83 m ha upto 2005-06. Improving the efficiency of water under rainfed situation holds a promise to increase the productivity. Frontline demonstration results showed a large gap between farmers' yield and achievable yield. This gap can be filled considerably by adopting a sustainable management approach of natural resources. It requires knowledge of sound agronomic principles, broader understanding of constraints and interaction of biotic and abiotic stresses in developing crop genetic bases for diversifying production while ensuring the efficiency of resource use. Under rainfed conditions, the yield of deep-rooted crops in cracking clay soils (Vertisols) depends primarily on the amount of rain entered and stored at depth in soil profile, and the extent to which this soil water is released during the crop growth. Recent research results obtained at NBSS&LUP [16, 17, 19] indicate that both retention and release of soil water are governed by the nature and content of clay minerals, and also by the nature of exchangeable cations. In arid and semi-arid environment the subsoils become sodic due to accelerated rate of formation and accumulation of pedogenic $CaCO_3$. This process impairs the sHC. Therefore, it has become imperative to revise the AESR boundaries incorporating revised LGP estimates based on soil properties. AESR map is a useful tool to plan the crop suitability based on length of growing period. The revision of LGP estimates involving the influence of drainage related soil properties might provide a better insight into the AESRs. It might also involve revising AESR boundaries to bring the latest soil, climate information generated during the last 20 years.

Key words : Agro-ecological zones, crop evaluation

Development of Agro-ecological Zones

Food and nutritional security on sustainable basis are the major challenges of the 21st Century. The domestic production needs to be increased @2% for cereals and pulses and 6.0 % per annum for oilseed to meet the projected demand by the year 2030 [1].

The speed of the expansion of irrigation potential of 140 m ha is very tardy at present. Irrigation has been possible in only 83 m ha upto 2005-06. Improving the efficiency of water under rainfed situation holds a promise to increase the productivity. Frontline demonstration results showed a large gap between farmers' yield and achievable yield. This gap can be filled considerably by adopting a sustainable management approach of natural resources [2]. It requires knowledge of sound agronomic principles, broader understanding of constraints and interaction of biotic and abiotic stresses in developing crop genetic bases for diversifying production while ensuring the efficiency of resource use [3].

In this endeavour highest priority needs to be given to assess land/water and climate resources to create an integrated system to apply the best of scientific technology and knowledge for agricultural development through effective policies for public and private investments and institutions [4]. The task was to create a near homogeneous soil-climatic regions that is compatible for sustenance of a particular group of crops and cultivars. Thus, a near homogenous area which are similar in respect of soil, bioclimate and moisture availability related to crop production is known as Agro-ecological Zones (AEZ) [5]. FAO's exercises concentrated on creation of broad crop feasibility zone based on length of moisture availability period superimposed on FAO/UNESCO global soil and terrain map on 1:5000,000 scale. The AEZs so created are very broad to use for crop planning both at state and district levels.

In India, several attempts have been made to classify the land area into climatic regions. Krishnan

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and Singh [6] delineated soil climatic zone by superimposing moisture index and mean air temperature isopleths on broad soil types of India. Murthy and Pandey [7] brought out 8 Agro-ecological Regions (AER) map on the basis of physiography, climate (rainfall and potential water surplus/deficit), major soil and agricultural regions. These two approaches were the modest beginning of agro-ecological zoning of the country. However, they suffer from several limitations due to over generalization, such as grouping together the areas, having different physiography, temperature and soils in a zone. For example, Rajasthan desert, Indo-Gangetic Plains (IGP) and Eastern Himalayas were grouped in one AER. Likewise, Jammu and Kashmir, Himachal Pradesh and north-western Uttar Pradesh were also grouped into the same region [7]. Based on data of 1600 meteorological stations and also using the concept of moisture adequacy index (IMA) (AE/PETx100), Subramaniam [8], delineated 29 Agro-ecological Zones (AEZ) with 36 combinations of IMA and dominant soil groups of FAO/UNESCO Soil Map [9]. However, this attempt did not consider other important parameters such as physiography and bioclimate. This inadequacy resulted in grouping both cold arid and warm humid regions of Jammu and Kashmir in one zone. Similarly, north-west and north-east Himalayas having contrasting agro-climatic conditions were also grouped in one zone. Therefore, this approach may not permit in bringing out an uniform AEZ for practical crop planning. The Planning Commission, Govt. of India, divided the country into 15 broad Agro-Climatic Zones (ACZ) [10] based on physiography and climate with a view to develop the resources and their optimum utilization in a sustained manner within the framework of resource constraints and potential of each region. Following this the State Agricultural Universities (SAUs) were advised to divide each zone/state into subzones under National Agricultural Research Project (NARP). Accordingly, 127 sub-zone map, based primarily on rainfall, existing cropping pattern and administrative units was developed. The environmental conditions namely soil, water and climate were not considered. Moreover, use of state as units for subdivisions resulted in many sub-zones showing similar agro-climatic characteristics.

Development of Agro-ecological Zones – NBSS&LUP Concept

NBSS&LUP (ICAR) mooted the concept of length of growing period (LGP) [5] to address inadequacies in the above mentioned protocols for agro-ecological zones/regions. The LGP is an index of crop production because it takes care soil-water balance, which is a direct function of moisture availability in a landform rather than total rainfall. In addition, LGP allows to compute modification in quantum of residual moisture when the soil depth is less than 100 cm. The 20 Agro-Ecological Regions (AERs) was delineated by the NBSS&LUP by superimposing bioclimate and LGP on soilscape. The LGP classes were clubbed apparently related to cropping in an agro-environment [11]. While developing AER only 5 LGP classes were considered showing due importance to crop durations such as short (<90 days), medium (90-150 days), long (150-180 days), relay cropping (180-210 days) and double cropping (>210 days). Realising the importance of narrower LGP interval of 30 days for diverse crop suitability and also the need of further subdivisions of bioclimate and some important soil quality parameters like depth and available water capacity (AWC), NBSS&LUP divided 20 AER into 60 Agro-Ecological Subregions (AESRs) [12].

Usefulness and Revision Needs of AESR

Usefulness of 60 AESRs has been demonstrated in estimating soil carbon and available potassium stocks of the IGP and black soil regions and also in prioritizing areas of carbon sequestration [13,14]. Inspite of this, refinement of AESR boundaries to match rainfall with crop water requirement has been realized for quite some time. However, to address this issue there is a need to gather antecedent soil moisture, after the cessation of rains when rainfall (P) falls short of 0.5 potential evapotranspiration (PE). In absence of such essential data the present AESR boundaries vis-à-vis crop performance exhibit scenarios a little away from reality under adverse soil condition and those can be comprehended through following examples.

Scenario 1 : Nagpur, Amravati and Akola districts of Maharashtra occur in sub-humid dry to semi-arid moist bioclimatic zones and belong to contiguous AESR 10.2 and 6.3. The water balance from these districts, based on 30-year climatic data indicates that the humid and length of growing periods of Nagpur [15] are 103 days and 183 days, respectively. Both Amravati and Akola districts have shorter humid periods and length of growing periods than Nagpur. Although there is a difference of 6 days in humid periods between Amravati and Akola [16], the growing periods are almost the same (152 versus 150 days). Under similar soil management by farmers in 29 deep cracking clay soils (Vertisols) areas, and also under similar soil moisture and temperature regimes, yields of cotton (seed + lint) were better in soils of Nagpur (1.0 – 1.8 t/ha) than those of

Amravati (0.6-1.7 t/ha) and Akola (0.6-1.0 t/ha) [16,17]. The subsoils in the western part of Amravati and Akola districts are becoming sodic due to accelerated rate of formation and accumulation of pedogenic $CaCO_3$ [17]. This impairs hydraulic conductivity (sHC) of Vertisols and impairs crop yield as evidenced by a significant positive correlation between yield of cotton and sHC [16]. This relation exists despite the fact that both the soils indicate considerable amounts of available water capacity (AWC) [16]. It demands a revised concept for quantification of LGP to make it more worthwhile and robust crop-linked soil-climate parameter.

Scenario 2 : Deep cracking clay soils (Vertisols) at Sokhda and Semla benchmark sites of Gujarat represent semi-arid (dry) and arid (dry) bioclimatic zones and belong to AESR 5.1 and are cultivated for cotton. Despite climatic aridity-related soil degradation [18], cotton yields are 1.8 t ha^{-1} to 2.0 t ha^{-1} in Sokhda and Semla Vertisols and resemble similar crop performance in wetter part of the country namely in AESR 10.2 and 6.3. These yields are comparable to those obtained in Vertisols of Nagpur district under sub-humid dry bioclimatic zone. Presence of Ca-zeolites act as natural soil modifiers to ward off the adverse effects of Na^+ ions and thus manage to produce crop yield similar to wetter climate [19]. This shows that different AESRs, can capture similar performance of cotton in Vertisols. The management practices (irrigation, crop variety) can overshadow the boundaries of AESRs. The present example shows how a natural modifier can help to cut across the boundaries of AESR if crop performance is considered as an important parameter. This suggests that assuming 100 mm as moisture stored in shrink-swell soils after rain to calculate length of growing period (LGP) [15, 20] is inappropriate and needs a relook.

Scenario 3 : Wheat productivity of 2005-2008 (Fig. 1) in soils of the IGP indicates that states like Punjab and Haryana (AESR 9.1 and 9.2) , produces nearly 4.5 t/ha of wheat whereas Bhojpur district of Bihar representing AESR 9.2 produces only 1.6 t/ha [21]. However, the soils of Punjab and Haryana do not experience waterlogging (Haplustepts and Haplupepts) like Bihar soils. This suggests again that calculation of LGP needs some modification to indicate the real soil moisture situation in these areas.

In Rajasthan, some Vertisols (Jhalipura, Kota district) of semi-arid (dry) bioclimatic region are grown for wheat and its yields (4.5 t/ha) are comparable to those of Punjab and Haryana despite the fact that the texture of Vertisols are clayey and believed to have poor

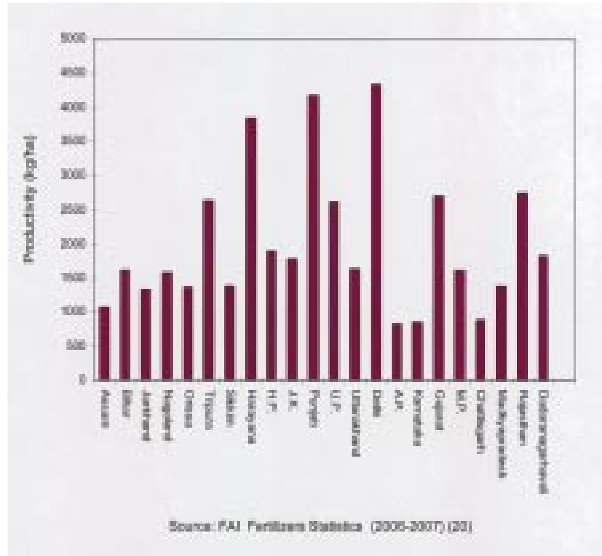

Fig.1. Wheat productivity (kg/ha) in different states of India (2005-2006)

drainage conditions. However, Vertisols of this area contain Ca-zeolites which help improving the sHC >10 mm/hr [22]. This indicates that the entry of rain water in soil profile is the most important issue in rainfed agriculture.

Conclusion

Under rainfed conditions, the yield of deep-rooted crops in cracking clay soils (Vertisols) depends primarily on the amount of rain entered and stored at depth in soil profile, and the extent to which this soil water is released during the crop growth. Recent research results obtained at NBSS&LUP [16, 17, 19] indicates that both retention and release of soil water are governed by the nature and content of clay minerals, and also by the nature of exchangeable cations. In arid and semi-arid environment the subsoils become sodic due to accelerated rate of formation and accumulation of pedogenic $CaCO_3$. This process impairs the sHC. Therefore, it has become imperative to revise the AESR boundaries incorporating revised LGP estimates based on soil properties.

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