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# Moisture availability and its application in evaluating agriculture potential in semi-arid region

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**सार** — पंजाब और हरियाणा राज्य सामान्यत : भारत के शुष्क और अतिशुष्क विभागों में आते हैं। आर्द्रता उपलब्धि सूचकांक (MAI) का उपयोग करके इन्हें और चार विभिन्न कृषि जलवायु क्षेत्रों में वर्गीकृत किया गया है। ये हैं, बहुत कम क्षमता वाले (VLP) कम क्षमता वाले (LP) मध्यम क्षमता वाले (MP) और उच्च क्षमता वाले (HP)।

बहुत कम क्षमता वाले क्षेत्रों में फसल की संभावना साल में केवल 20–30% हैं। कम क्षमता वाले क्षेत्र में वर्षा पर आधारित, 10–12 हफ्तों में तैयार होने वाली फसल हो सकती है, बल्कि मध्यम क्षमता वाले क्षेत्र में फसल की क्षमता थोड़ी सी ज्यादा है। खेती को ध्यान में रखकर यदि देखा जाए तो उच्च क्षमता वाला क्षेत्र सबसे अच्छा और जोखिम से बाहर है। उपरिनिर्दिष्ट हर एक क्षेत्र में एक स्थान को लेकर, विभिन्न जोखिम स्तरों पर फसल की संभावनाओं पर इसमें चर्चा की है।

ABSTRACT. The States of Punjab and Haryana generally belong to part of arid and semi-arid regions of India. An index known as Moisture Availability Index (MAI) has been used to demarcate it into different agroclimatic zones. The four zones identified were named Very Low Potential (VLP), Low Potential (LP), Moderate Potential (MP) and High Potential (HP) zones.

The zone VLP had the lowest crop potential area where crops are possible in only 20-30% of the years. A short duration rainfed crop of 10-12 weeks duration may be grown from zone LP while in area MP the crop growing potential is slightly more. From agricultural point of view area HP appears best suited with minimum risk. Crop prospects at one station in each zone at various risk levels have also been discussed.

## 1. Introduction

The basic requirement for a study of dryland farming is a knowledge on rainfall pattern and water availability periods. A certain amount of rainfall need not necessarily indicate that all the amount will be used up by the crop, because the same amount of water behaves differently, depending upon the atmospheric demand of the place and type and depth of the soil. Also chances of occurrence of a specified amount of rainfall is useful for evolving a suitable cropping pattern. This is particularly the case in arid/semi-arid regions where rainfall is highly erratic in time and space.

The moisture availability index (MAI) which is the ratio of rainfall at 50% probability level to the potential evapotranspiration (PE) has been used in recent years for agroclimatic zoning and assessing crop prospects (Wallen & Perrin 1962, Sarker *et al.* 1982, Sarker & Biswas 1986, Khambete and Mondal 1986 etc).

The present study attempts to evaluate crop potential in the States of Punjab and Haryana where arid to semi-arid conditions are prevalent.

## 2. Data

Weekly rainfall data of 73 well distributed stations of Punjab and Haryana have been used for this study. Length of data varies from 50 to 70 years. From the daily rainfall values, weekly figures were computed for standard weeks. These weekly values were then used to compute probabilistic rainfall by fitting incomplete gamma distribution model. Values of 50% level was used to compute MAI for different weeks. In addition, MAI at 30, 40, 60 and 70 per cent has been computed and discussed wherever necessary. The weekly PE values were interpolated from the monthly values computed by Rao *et al.* (1971). Soil information was extracted from "Soil of India" (Alexander 1972).

## 3. Results and discussion

In order to divide the area into different agroclimatic zones, it is essential to know the number of weeks, MAI would assume values compatible with the water needs of the crops. Normally, towards the start of the growing season and also towards its physiological maturity stage, many authors believed that 25% of the PE is quite adequate (Riplay 1966). This 25% PE generally correspond to a weekly MAI of 0.3. In the active growth phase, Jenson (1968) observed that for many farm crops, water use may range from 55 to 75% of PE. Venkataraman *et al.* (1976) also found that for wheat crops at Akola, Pune and New Delhi the evapotranspiration is about 70% of PE. Biswas and Khambete (1986) concluded

from a study of lysimeter data that sorghum and millet used water 61 and 66 per cent of PE respectively during the life span of these crops and 30-35% during germination stage. In view of above, in the present study, it has been used two thresholds of MAI, *i. e.*, 0.3 and 0.7 at 50% level. The number of weeks arbitrarily divided into different ranges to evolve the following agroclimatic zones :

| *No of weeks with MAI* | | *AAR (mm)* | *Agricultural potential* | *Agroclimatic type* |
|---|---|---|---|---|
| $\geq 0.3$ up to 4 | $\geq 0.7$ upto 3 | up to 100 | Very low potential | VLP |
| 5-7 | 4-6 | 100-200 | Low potential | LP |
| 8-10 | 7-9 | 200-300 | Moderate potential | MP |
| $\geq 11$ | $\geq 10$ | $\geq 300$ | High potential | HP |

In the earlier classification where thresholds weeks with 0.3 and 0.7 were used, it was observed that in many cases, the criteria are not uniquely satisfied. Accumulated assured rainfall (AAR) amount is an important parameter for any planning. It is, therefore, most appropriate that this vital factor is not ignored while delineating a regimes into agroclimatic types.

At many of the places, all these criteria mentioned above were satisfied simultaneously. However, in a very few cases when it was not so, the station was assigned the category satisfied by 2 of the three criteria.

On the basis of the above classification the areas demarcated has been shown in Fig. 1 and discussed below.

3. 1. (a). *Very low potential (VLP)*

Southwestern parts of the region belong to this category. The area stretches from Ferozepur to Bhiwani district through Jodhpur and Hissar districts. Parts of Nathana tehsil in Sangrur district, Rohtak and Salhawas tehsils in Rohtak district also belonged to this type.

The values of MAI in this zone are characteristically low. It is seen that at 50% probability level only one third of the water demand is met for maximum period of a month or so. Computing this dismal moistured situation, the AAR also does not exceed 100 mm in fact in some of the locations it is as less as 20 mm.

(b). *Low potential zone (LP)*

Orientation of this zone, like the first one is NW-SE. Amritsar, Taran Taran, Bhuchar and Khara tehsils in Amritsar district, Moga and Zira tehsils in Ferozepur district, all the tehsils in Sangrur district (except Nathana, Gulab, Kaithal) and Rajaund tehsil in Karnal district nearly the whole of Rohtak district (except Salhawas) and western fringe of Gurgaon district, belong to this category.


Fig. 1. Agroclimatic zoning of Punjab and Haryana

The moisture availability period is marginally high in this zone than the former. Crop potential is low at 50% level but at 30% level MAI's $>.3$ and .7 are about 12 and 6 weeks respectively. AAR is also nearly double than that in zone VLP.

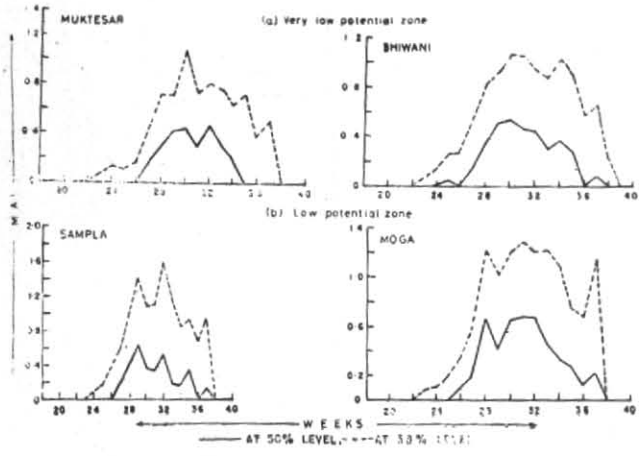
(c). *Moderate potential (MP)*

The area comprises of Batala tehsil in Gurdaspur district, Ajnala in Amritsar district, central parts of Jullundar, Ludhiana, Patiala and Karnal districts and most of Gurgaon district and New Delhi. During the crop season 200-300 mm of rainfall could be expected at 50% level of probability. As compared to earlier zones duration of the weekly MAI is also high. At 30% level duration of MAI more assured than .3 and .7 are of the order of 12-14, and 8-9 weeks. AAR is about 400 mm.

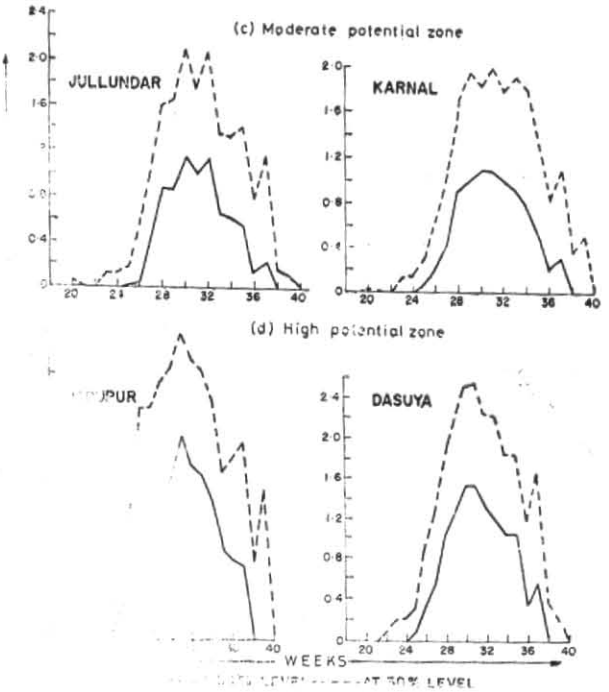
(d). *High potential (HP)*

The rest of the region belong to HP category. It consists of rainy parts of Gurdaspur district, Hoshiarpur district, Ambala district and NW parts of Karnal district.

Crop potential is high in these zone as MAI $>.3$ at 50% level is more than 11 weeks and AAR is also about




Figs. 2(a-b). MAI at crop growing periods at 50% and 30% level for (a) Very low and (b) Low potential zones




Figs. 2(c-d). MAI at crop growing periods at 50% and 30% level for (c) Moderate and (d) High potential zones

300 mm. At 30% level MAI's >.3 and .7 are more than 14 and 10 weeks. AAR is of the order of 500 mm, hence residual moisture will be available at the end of rainy season. Thus a farmer is sure that in this zone the crop water requirement can be met at any point of growth, at 50% level of confidence. All these factors, indicate that this zone has the largest potential of rainfed agriculture in the areas under consideration.

3. 2. *Crop growing periods*

The technique also enables one to determine the length of growing period at different probability levels, the following assumptions are made:

(*i*) The crop for sowing and initial growth, need at least 25% of the potential demand,

(*ii*) During the active growth, the demand is at least 60 -70% of PE,

(*iii*) At the physiological maturity stage, the crops demand it again 25%.

For each of the four agroclimatic zones, we have selected 2 stations and the ratio of assured rainfall to PE has been computed for each weeks and shown in Fig. 2 for the sake of clarity, only 2 probability levels of rainfall, *viz.*, 30% and 50% have been depicted.

(a). *Very low potential* (*VLP*) *zone* — The start of sowing at 50% level in this zone could be 27th week and the end of the crop season is at 34th week [Fig. 2(a)]. Normally at this level the crop season is highly restricted. The period of the crop season at 30% level is large spanning from 26th to 38th week. The AR/PE ratio exceed one in some of the weeks and water demand is also met.

(b). *Low potential* (*LP*) *zone* — This zone offers somewhat better prospects than the earlier zone [Fig. 2(b)]. In this zone sowing could commence in 27th week at 50% level and 26th week at 30% level. The end of growing period at these levels are 36th and 37th week respectively. The corresponding crop growth duration will thus be 11 and 13 weeks. As such in this zone too, crops with a life cycle of 90 days can be raised at 30% level only. At 50% level, water need is never satisfied in full and at 30% level, for most of the weeks on the active growth stage the AR/PE ratio exceeds 1.0.

(c). *Moderate potential* (*MP*) *zone* — As may be seen in Fig. 2 (c), crop season can commence in 26th and 25th week respectively at 50% and 30% levels in this zone. The weeks in which AR/PE ratio falls back to 0.2 or less is 37th and 38th weeks respectively. The crop season at 50% level works out as 12 weeks and at 30% level as 14 weeks. As such a shorter duration crop appear feasible at 50% level and a crop of somewhat longer duration could be cultivated at 30% level. At 50% level AR/PE ratio exceed 1.0 for hardly 2 to 3 weeks while at 30% level it is fairly long. This suggest that in active growth phase when water need of the crop is maximum, the demand of the crop is fully met and some surplus water is available for soil recharge.

(d). *High potential* (*HP*) *zone* — It has been already mentioned that among the agroclimatic zones demarcated in this study, this zone has the largest crop potential. This is also reflected in the crop season and AR/PE values at 50 and 30% levels [Fig. 2(d)]. At 50% level, sowing could be undertaken at 25th week and in 37th week, AR/PE ratio is about 0.2. It is also observed that the ratio exceed 1.0 in many times between 27th and

35th week and in some location it was found to attain a value of even 1.5 for a brief period. The situation is still more promising at 30% level when :

(*i*) The sowing appears feasible at 25th week (18-24 June),

(*ii*) The growth could be last up to 39th week (24-30 Sep),

(*iii*) From 27th to 36th week (2 Jul to 9 Sep) the AR/PE ratio remain greater than 2.0. Rainfall is, thus, twice as large as evapotranspirative demand in some spells of crop growth,

(*iv*) Crop can thrive on stored moisture for about 4 weeks. Thus in this zone crops of 15 to 18 weeks duration can be raised at 30% level while at 50% level short to medium duration crops could be profitably grown.

#### 4. Identification of drought prone areas

Superimposing the agroclimatic zones on soil map, it is possible to demarcate areas liable to drought risks of various degrees. In the present study the following criteria was adopted for this purpose :

| *Soil type* | *Agroclimatic zones* | *Drought proneness* |
|---|---|---|
| (1) Desertic soil | Very low crop potential zone | Extremely drought prone |
| (2) Desertic soil<br>Sierozen soil | Low crop potential zone<br>Low and very low crop potential zone | Highly drought prone |
| (3) Arid brown soil<br>Brown soil<br>Sierozen soil | Very low crop potential zone<br>Low potential zone<br>Moderate potential zone | Moderately high drought prone |
| (4) Tropical arid brown<br>Arid brown<br>Tropical arid brown | Low crop potential zone<br>Moderate crop potential zone<br>Moderate crop potential zone | Moderately drought zone |
| (5) Tropical arid brown soil | High potential zone | Low drought prone |
| (6) Reddish chestnut soil, grey brown soil | High potential zone | Least drought prone |

The results of the analysis is shown in Fig. 3. It may be mentioned that the above classification is purely arbitrary though due importance was given to the soil characteristics and the probabilistic rainfall in identifying drought proneness of various regions. The results are discussed below.

4. 1. *Extremely drought prone* — A narrow strip from Ghagghar tehsil to Loharu in Hissar district (*i. e.*, southwest part of Hissar district) appears very highly drought prone. This area needs special attention for development of agriculture.

4.2. *Highly drought prone* — Ferozepur, Mukteswar, Fazilka, Abohar, Govindgarh, tehsils in Ferozepur district, Bhatinda district, Nathana tehsil in Sangrur district and Sirsa, Fatehabad, Hansi and Bhiwani in Hissar district, come under this category. Soils in this area are somewhat better though growth periods are short. Thus this area appears less prone to drought compared to the former.

4.3. *Moderately high drought prone* — This area comprises of Amritsar, Bhuchar, Khara, Taran-Taran tehsils in Amritsar district, Moga, Zira tehsils in Ferozepur district, part of Jagraon tehsil in Ludhiana district, Sangrur district, Gulah, Kaithal, Rajaund tehsils in Karnal district and Gohana, Sonepat, Sampla tehsils in Rohtak district. The soils are somewhat better in this area but moisture availability is not that promising to assign it a lower drought risk level.

4.4. *Moderately drought prone* — Moisture spectrum increases considerably from SW to NE, hence, the drought proneness decreases. Moderately drought prone zone could be identified over Aliwal, Batala tehsil in Gurdaspur district, Jullundar, Nakodar tehsils in Jullundar district, part of Ludhiana district through Patiala district and Panipat, Karnal district.

4.5. *Low drought prone* — It consists of Samrala tehsil in Ludhiana district, Naraingarh, Ambala, Jagadhri of Ambala district and part of Thanesar tehsil of Karnal district. This zone appears better placed in respect of soil and rainfall characteristics and is thus subjected to low drought risk.

4.6. *Least drought prone* — The high crop potential area with red chestnut soil and grey brown soils seems liable to least drought risk. This consists of Pathankot, Gurdaspur, Tibri tehsils of Gurdaspur district through Hoshiarpur district and Dadupur, Rupar, Kharar tehsils in Ambala district. Drought proneness in this area being least agriculture could be so planned that maximum production is achieved.

It may be mentioned that in earlier drought studies (George *et al.* 1973, Mooley and Parthasarathy 1982, Chowdhury and Abhyankar 1984), the whole of Punjab and Haryana was termed as drought prone. The present analysis clearly brings out that though a major chunk in the area is no doubt subjected to drought proneness of various degrees, there are still few areas in which the drought risk is rather low.

Agriculture could be developed in each areas to exploit to the utmost, the favourable climatic and soil features. In areas where drought risks are high large scale supplementary irrigation should be planned to cover the moisture stress period or evolve alternate cropping strategies.

#### 5. Conclusion

The analysis bring forth the following conclusions:

(*i*) On the basis of assured rainfall and moisture availability index the arid zones in Punjab and Haryana could be divided into 4 zones.

(*ii*) These zones have, in general, NW-SE orientation and reveal more moisture, availability from southwest to northeast.

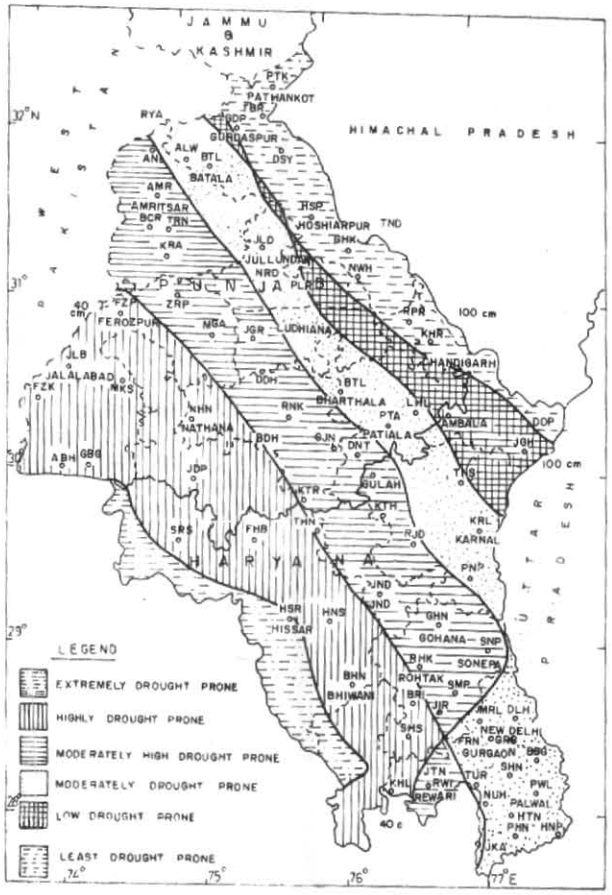



Fig. 3. Drought proneness of various degrees for Punjab and Haryana

(*iii*) In the vicinity of the desert the areas have least crop potential while the foothills of Shiwalik range have maximum potential.

(*iv*) The area under study could be divided into six zones of drought proneness with its southwestern fringe liable to very high drought risk.

(*v*) A strip from NW to SE, bordering Jammu and Himachal Pradesh appears least subjected to drought proneness.

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## APPENDIX I

### The standard weeks

| Week No. | | Dates | Week No. | | Dates |
|---|---|---|---|---|---|
| 1 | January | 1-7 | 27 | July | 2-8 |
| 2 | | 8-14 | 28 | | 9-15 |
| 3 | | 15-21 | 29 | | 16-22 |
| 4 | | 22-28 | 30 | | 23-29 |
| 5 | | 29-4 | 31 | | 30-5 |
| 6 | February | 5-11 | 32 | August | 6-12 |
| 7 | | 12-18 | 33 | | 13-19 |
| 8 | | 19-25 | 34 | | 20-26 |
| 9 | | 26-4* | 35 | | 27-2 |
| 10 | March | 5-11 | 36 | September | 3-9 |
| 11 | | 12-18 | 37 | | 10-16 |
| 12 | | 19-25 | 38 | | 17-23 |
| 13 | | 26-1 | 39 | | 24-30 |
| 14 | April | 2-8 | 40 | October | 1-7 |
| 15 | | 9-15 | 41 | | 8-14 |
| 16 | | 16-22 | 42 | | 15-21 |
| 17 | | 23-29 | 43 | | 22-28 |
| 18 | | 30-6 | 44 | | 29-4 |
| 19 | May | 7-13 | 45 | November | 5-11 |
| 20 | | 14-20 | 46 | | 12-18 |
| 21 | | 21-27 | 47 | | 19-25 |
| 22 | | 28-3 | 48 | | 26-2 |
| 23 | June | 4-10 | 49 | December | 3-9 |
| 24 | | 11-17 | 50 | | 10-16 |
| 25 | | 18-24 | 51 | | 17-23 |
| 26 | | 25-1 | 52 | | 24-31@ |

* In leap year the week No. 9 will be 26 February to 4 March, *i.e.*, 8 days instead of 7.

@ Last week will have 8 days, 24 to 31 December.