Journal of Agrometeorology 15 (Special Issue-I) : 13-19 (March 2013)

Climate change projections - A District-wise analysis for rainfed regions in India

C.A. RAMA RAO*, B.M.K. RAJU, A.V.M.S. RAO, V.U.M. RAO, K.V. RAO, KAUSALYA RAMACHANDRAN and B. VENKATESWARLU

Central Research Institute for Dryland Agriculture, Hyderabad - 500 059, Andhra Pradesh

**E-mail: carrao@crida.in*

ABSTRACT

Rainfed agriculture is practised in arid, semi-arid and dry-sub-humid- regions of the country. The climate projections are reported generally at the all India level or at the resolution of grids of different dimensions. This paper attempted to derive and report the climate projections given by the PRECIS for A1B scenario in the form agriculturally relevant variables for 220 districts where rainfed agriculture is predominant. Districts with an average rainfall of less than 1500 mm and are included either in DPAP or DDP and those with less than 30 per cent of net sown area under irrigation are included in the study. The climate projections provided at a grid size of 50 x 50 km are converted into district level estimates. Annual rainfall is projected to increase by more than five per cent in 173 districts and decrease by more than five per cent in 42 districts during the mid-century compared to the baseline. The later part of the century is likely to be much wetter with 205 districts showing an increase in rainfall by more than five percent and only five districts projected to receive relatively less rainfall. The number of rainy days is projected to not change much in a majority of districts during the both periods. The end-century is likely to witness much variability in the onset of monsoon, which is projected to arrive late by more than five days in 42 districts. Incidence of drought is observed to increase in 62 districts during mid-century and in 134 districts during the end-century. The average maximum temperature is projected to increase by 1.5 to 2^{0}C in a majority of districts during mid-century and by more than 2^{0}C in a few districts. Temperature is likely to be much warmer during the end-century with projections of 3.5 to 4^{0}C in most districts. These projections have implications to planning and targeting technology development and transfer as well as planning for development interventions.

Key words: Rainfed agriculture, climate change, PRECIS, rainfall, drought incidence

Agriculture in India is largely rainfed with nearly sixty per cent of the 142 m ha of net sown area having no access to irrigation (Venkateswarlu and Rama Rao, 2010). Rainfed agriculture, often referred to as dryland agriculture, is practised in areas that are relatively warmer – arid, semi-arid and dry-sub-humid- regions of the country. In these regions, the annual precipitation falls short of the potential evapo-transpiration demand. This together with lack of access to irrigation results in agriculture that is dependent on monsoon rains which are known to be inadequate, erratic and undependable. Not only is the course of the monsoon during a season unpredictable, but also the inter-annual variation in the rainfall is high in these regions. Traditionally, rainfed regions are major producers of coarse cereals, pulses, oilseeds and cotton. Majority of coarse cereals (87.5%), pulses (87%), oilseeds (77%) and cotton (67%) are largely grown on drylands (CRIDA, 2007). Changing and increasingly variable climate, another important issue increasingly recognized as a formidable challenge to ensuring food security in developing countries and engaging the global community, adds the dimensions of urgency and complexity to the problems of rainfed agriculture.

There is now adequate evidence about the impending climate change (CC) and the consequences thereof. The fourth assessment report of IPCC observed that 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level' (IPCC, 2007). Climate change is increasingly recognized as a potent threat to agriculture in general and to food security in particular of global populations. Climate change projections made for India indicate an overall increase in temperature by 1-4^{0}C towards 2050s and precipitation by 9-16% (Krishnakumar *et al.*, 2011). Climate change and variability also manifests not only in the form of changes in onset and withdrawal of monsoon, incidence of extreme events such as droughts and floods, number of rainy days, annual rainfall which have implications to agriculture. Climate change projections are generally reported at regional scale or at a spatial resolution of grids of different sizes which are essentially downscaled from the outputs of a particular global circulation model. Thus, they are not at consonance with the scale at which the planning for agricultural development is made. In India, district is the administrative unit where various development interventions are planned and executed. Therefore, availability of information regarding the possible changes in climate at such a scale will be of immense help to those concerned with agricultural development and research. It is with this view that this paper attempts to look at the changes in climate in terms of agriculturally relevant variables at district level.

MATERIALS AND METHODS

The analysis is done for 220 districts where rainfed agriculture is predominant. These districts are selected based on the following criteria: (a) Included in the centrally sponsored Drought Prone Area Programme (DPAP) or in the Desert Development Programme (DDP) or the net irrigated area is less than 30 per cent and (b) The average annual rainfall is less than 1500 mm. In addition, all the districts in the North Eastern States and states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand were not included in the analysis. Climatically, these districts represent arid, semi-arid, dry and moist sub-humid regions in the country.

There are a number of global circulation models and the corresponding versions of downscaled projections at a relatively smaller spatial resolution and these projections vary with the parent GCM. In this paper, we chose to use the projections obtained at a resolution of grid of 50 x 50 km using the PRECIS where the daily data on maximum temperature, minimum temperature and rainfall is available for the period 1961-2098. Though these estimates are available for different scenarios, we used the output for the A1B emission scenario as this showed 'reasonable skill in simulating the monsoon climate over India' (Krishnakumar *et al.,* 2011) and was considered as 'the most appropriate scenario as it represents high technological development, with the infusion of renewable energy technologies following a sustainable growth trajectory' (MoEF, 2012). Using the daily data on these variables, the relevant parameters are estimated (Table 1).

All the values at grid level were converted into district level estimates by obtaining the weighted average, with the area under a given grid falling into a particular district as weight, in case of rainfall-related parameters and by obtaining the simple average of all the grid values passing through a district in case of temperature related parameters. The above parameters were computed for the three periods – 1961-90 (baseline), 2021-2050 (mid-century) and 2071-2098 (end-century) and the results are presented in terms of change relative to baseline in order to account for the model bias in the estimates.

Table 1 : Description of the parameters estimated

Parameter	Description
Annual rainfall (mm)	Total amount of rainfall received during a year
Number of rainy days	Total number of days receiving at least 2.5 mm of rain
Onset of monsoon	First rainy day after June 1
Incidence of drought	A year is considered as a moderately drought year if the annual rainfall is less than 80 per cent and above 50 per cent of the normal rainfall and a year with rainfall less than half of the normal is considered as severely drought year (Gore *et al.,* (2010). Each severe drought year was considered equivalent to two moderate drought years. An index was then calculated as (number of moderate drought years + 2* number of severe drought years) / total number of years * 100.
Dry spells	Number of events of rainless period of at least 14 consecutive days during the monsoon (June to September). A day is considered as a rainless day if the rainfall is less than 2.5 mm
Extreme rainfall events	Number of events when cumulative rainfall in three consecutive days is more than 100mm
Maximum temperature	Maximum temperature recorded in a year
Minimum temperature	Minimum temperature recorded in a year

RESULTS AND DISCUSSION

It is observed that the annual rainfall is projected to increase by more than five per cent in as many as 173 districts and decrease by more than five per cent in about 42 districts in the states of Andhra Pradesh, Karnataka, Tamil Nadu, Jharkhand, Bihar and Maharashtra during the mid-century compared to the baseline (Fig. 1). The change in rainfall is expected to change little (-5 to +5%) in only five districts.

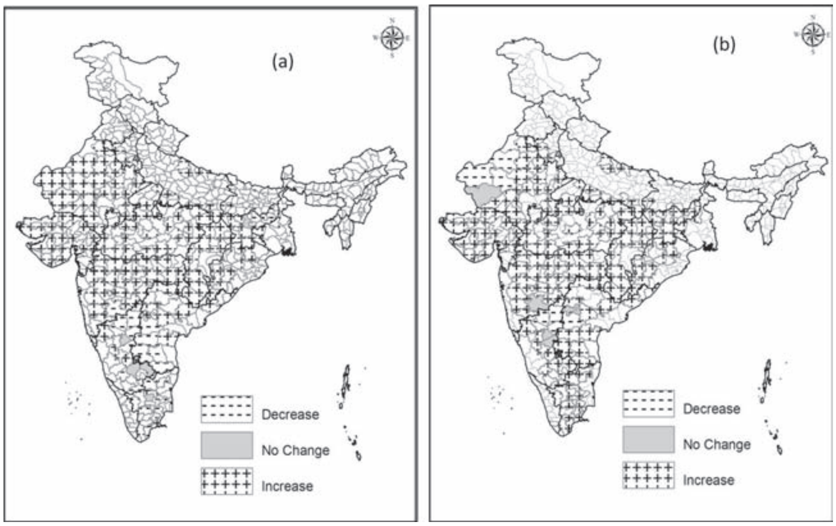

Fig. 1 : Changes in annual rainfall during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India

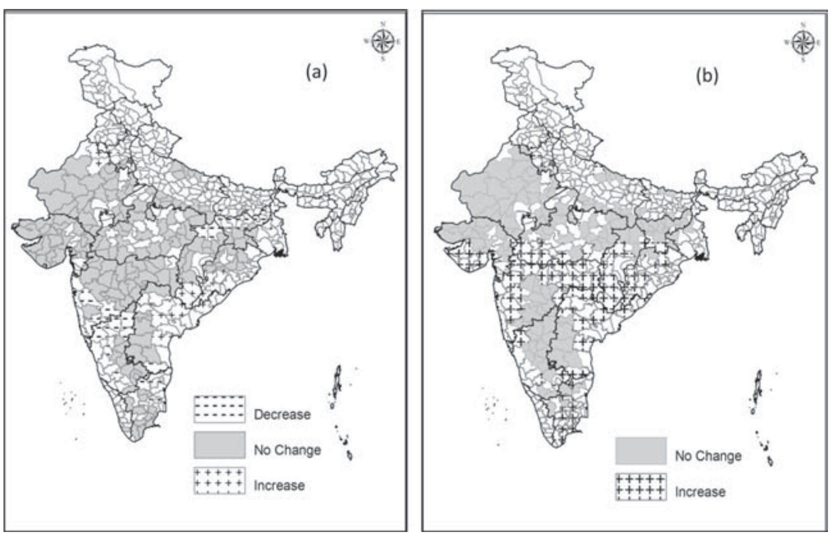

Fig. 2 : Changes in number of rainy days during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India

The later part of the century is likely to be much wetter with about 205 districts showing an increase in rainfall by more than five percent and only five districts projected to relatively less rainfall compared to the baseline. However, the rainfall is projected to decrease by more than five per cent towards the end of this century in a few districts in Rajasthan, Karnataka and Andhra Pradesh.

The number of rainy days is projected to not change much in a majority of districts during the both periods compared to the baseline (159 districts during mid-century and 126 districts during the end-century) (Fig. 2). However, forty one districts in Maharashtra, Karnataka, Tamilnadu, Chattisgarh and Jharkhand are likely to experience less number of rainy days during the mid-century. A few districts in Rajasthan, Andhra Pradesh, Orissa and Chhattisgarh are projected to have more rainy days. Towards the end of century, the rainy days are projected to increase in ninety four districts.

Onset of monsoon is a crucial determinant of cropping pattern as productivity of some crops is significantly influenced by time of sowing. The first rainy day after June1 in a year is considered as onset of monsoon and the difference with respect to the base line is considered as either advancement of delay. During the mid-century period, the onset of monsoon is projected to advance by 1 to 5 days in 106 districts and delay by same period in another 106 districts (Fig. 3). It is likely to delay by more than five days in eight districts. However, the end-century is likely to witness much variability in the onset of monsoon, which is projected to arrive late by more than five days in 42 districts located in Rajasthan, Gujarat, Maharashtra, Karnataka and Andhra Pradesh. The onset is within the range of ± 5 days relative to baseline in 166 districts and is projected to advance by more than five days in 12 districts in Uttar Pradesh, Bihar, Rajasthan and Haryana.

During the mid-century, thirteen districts are likely to be worse off with respect to incidence of drought projected to increase by more than one per cent and these are located in Rajasthan Chhattisgarh and Orissa (Fig. 4). However, the increase in drought incidence is reported in a larger number of districts during the end-century. In all, incidence of drought is observed to increase in 62 districts during mid-century and in 134 districts during the end-century.

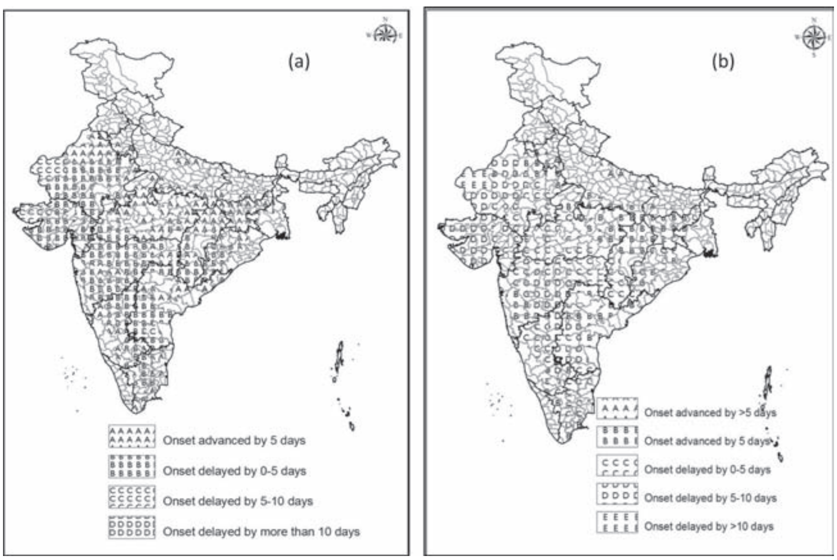

Fig. 3 : Changes in the onset of monsoon during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India

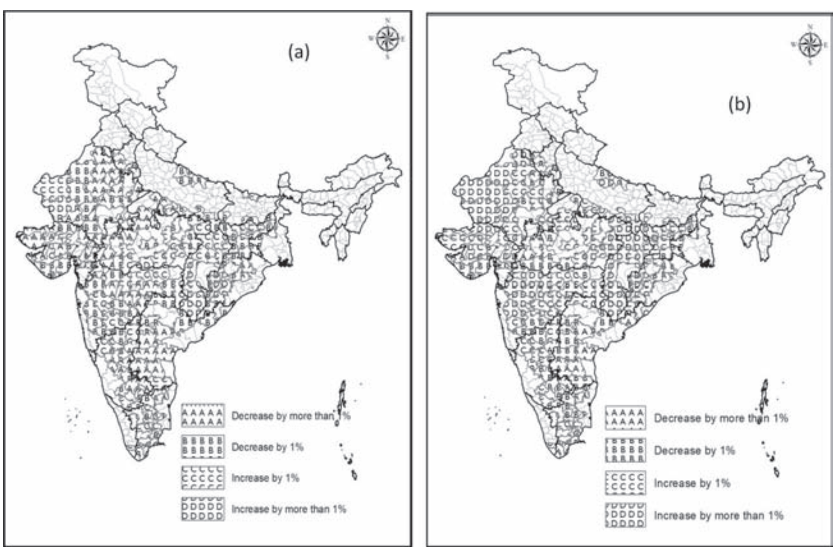

Fig. 4 : Changes in incidence of drought during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India (%)

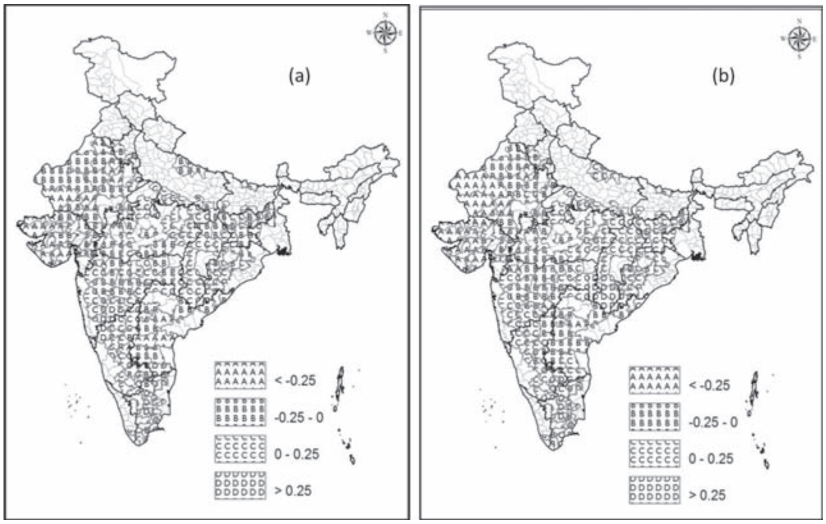

Fig. 5 : Changes in incidence of dry spells during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India (No/year)

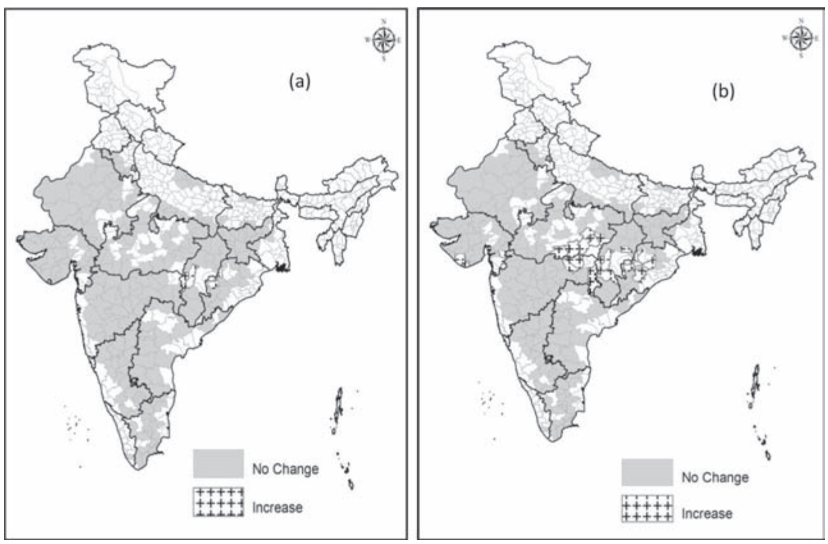

Fig. 6 : Changes in incidence of events of extreme rainfall during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India

Occurrence of dry spells of at least two weeks is observed to increase by 0.25 spells per year in a few districts in Tamil Nadu and southern Maharashtra and Chittoor in Andhra Pradesh during the mid-century and in south Karnataka, Tamil Nadu, Chhattisgarh and Madhya Pradesh during the end-century (Fig. 5). Some decrease in the incidence of dryspells is also observed in 24 districts Rajasthan, Gujarat and Andhra Pradesh during mid-century and in 25 districts in Rajasthan, Gujarat and Madhya Pradesh during the end-century.

Occurrence of extreme rainfall events is another threat to agriculture. These events, defined as occurrence of rainfall of more than 100 mm in three consecutive days, are projected to happen more frequently in four districts during the mid-century and in 24 districts during the end-century (Fig. 6). In the rest of the districts, the frequency is not likely to change by more than five per cent with respect to the baseline situation. The average maximum temperature is projected to increase by 1.5 to 2^0C in a majority of districts during mid-century and by more than 2^0C in a 17 districts located in Karnataka, Jharkhand and Bihar (Fig. 7). Temperature is likely to be much warmer during the end-century with projections of 3.5 to 4^0C in most districts. The minimum temperature is also projected to increase by 2.25 to 2.5^0C in a majority of the districts during the mid-century (Fig. 8).

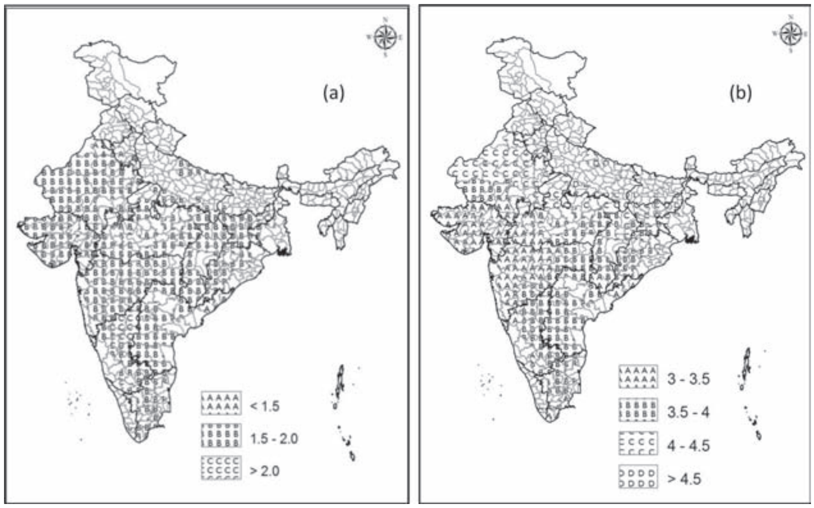

Fig. 7 : Changes in maximum temperature during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India (^{0}C)

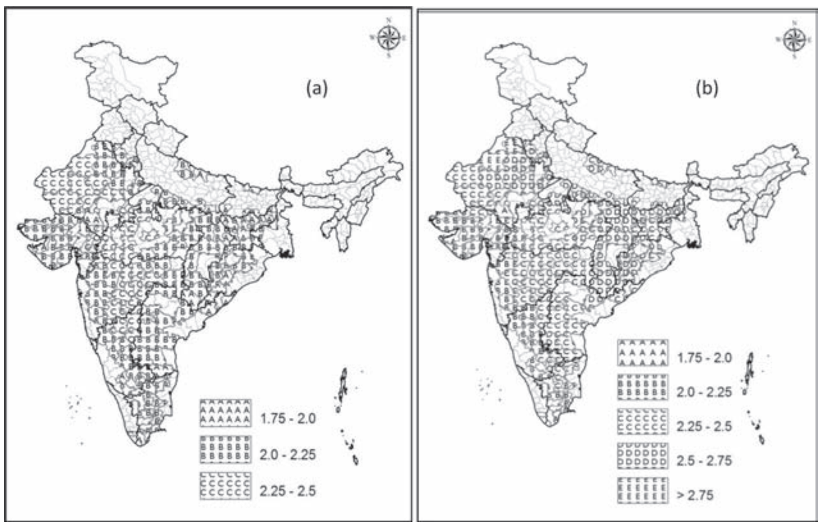

Fig. 8 : Changes in minimum temperature during (a) mid-century and (b) end-century relative to baseline in rainfed districts of India (^{0}C)

Increase in minimum temperature is more in a number of districts in Rajasthan, Madhya Pradesh, Maharashtra and Karnataka during the mid-century. The end-century is likely to witness much warmer nights with minimum temperature increasing by more than 2.5^{0}C in about 89 districts in much of the central and eastern India.

These projections have implications to planning and targeting technology development and transfer as well as planning for development interventions. For example, the options for crop choice have to be widened in case of where the onset of monsoon is projected to delay. Similarly, there is a need to enable life-saving irrigation through rainwater harvesting or more efficient irrigation methods in the areas where the incidence of dry spells are likely to increase. Increase in minimum temperature has implications to the yields of rabi crops such as wheat and hence efforts are needed to develop varieties or other technologies that enable better yields in the changing climatic conditions. Increase in the incidence of heavy rainfall events warrant attention on improved drainage as well as on the possibility of harvesting more rainwater to be used latter in the season.

CONCLUSIONS

Since district is the unit at which most of the development planning is done and other agro-economic data is also available, it is considered useful to derive climate projections at district level. Using the grid-level data on maximum temperature, minimum temperature and rainfall obtained through PRECIS for A1B scenario, district level estimates of total rainfall, number of rainy days, drought incidence, dry spells, maximum temperature, minimum temperature and extreme rainfall events were computed for three periods 1961-90 (baseline), 2021-50 (mid-century) and 2071-98 (end-century) and the results are presented in terms of change with respect to baseline situation. The findings indicated that both total rainfall and number of rainy days are likely to increase in a majority of districts. There are some districts where the number of rainy days is likely to decrease. Similarly, incidence of drought and dry spells are likely to increase and onset of monsoon is likely to delay in some districts where appropriate interventions are to be targeted. Increase in temperature, both maximum and minimum, is observed across the 220 rainfed districts and the increase is more conspicuous towards the end of century which has implications to crop yields, especially of rabi crops.

ACKNOWLEDGEMENT

This paper is an output of National Initiative on Climate Resilient Agriculture funded by ICAR.

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