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Effect of planting date choice on the vulnerability of winter wheat to climate change: Case study of cool temperate, northwestern provinces of Iran

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ABSTRACT

In this study, vulnerability to trend in length of 4 phonological stages (Initial, Anthesis, Maturity and Harvest) and total length of crop season (LCS) as a measure of climate change has been studied in 27 stations situated in 6 cool temperate provinces of north western Iran. Time series data for 25 years period between1989-90 to 2014-15 based on 8 scenarios for planting (sowing) date are studied to assess the effect of climate change on each station. The results show that late planting causes less vulnerability (except in Nahavand and Zarrineh stations) but also shorter crop season which is unfavorable. The Anthesis and Initial stages are most affected but Maturity and Harvest stages seem to be indifferent to climate change. Correct management training and disposal of hospital wastes should be one of the operational objectives of hospital managers and this important issue should be included in planning courses for staff of all hospitals.

KEY WORDS: IRAN, WINTER WHEAT, GROWING DEGREE DAYS, PHENOLOGY, CLIMATE CHANGE, PLANTING DAT5E

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INTRODUCTION

Winter Wheat is one of the strategic agricultural products of Iran. This variety of wheat has the best yield and quality in north-western provinces of country, including West and East Azerbaijan, Ardabil, Zanjan, Kordestan and Hamedan. Despite the fact that the mentioned region has the area of 17578000 acres or nearly 16.3% of the country area, the area under cultivation of winter wheat in these provinces consist about 40% of total wheat cultivating farms in the country or about 2411000 acres. This implies that the region is prone of cultivating wheat (and also other agricultural products) about 2.3 times more than other parts of country.

Another fact that verifies this is fraction of area under cultivation of wheat per total province area. Among 31 Iranian provinces, ranking of this statistic shows that all the provinces in selected area rank below 10, including first rank in country, Hamedan Province with 21.2% of its area under cultivation of wheat, Second rank Ardabil Province with 20.0%, rank 4 Kordestanprovince with 18.4%, rank 6 Zanjan provinces with 14.1% and finally, rank 9 and 10 East and West Azerbaijan provinces with 9.7% and 9.6% respectively.

Although the most important source of impact on yield of wheat, especially in dry farming, is adequate and timely precipitation, the climate change and global warming plays an undeniable role on long-term trends and attitudes toward choice of new places for building farms to answer the consistently increasing demand for this strategic product.

Choice of planting date is also a key factor and is studied to assess its impact on yield of many crops, specially wheat and maize. (Gomez-Macpherson and Richards,1995; Radmehr et al., 2003; Turner, 2004). For example Epplin et al. (2000) showed that a 3-week change in planting date of winter wheat, from 1 to 21 September is associated with an expected 44% increase in grain yield but the foliage yield drops 68%.

Tsimba et al. (2013) studied the effect of planting date on maize phonological stages in cool temperate sites across New Zealand. They showed that emergence-anthesis duration was longest for the earliest plantings, averaging 890°Cd vs. 830°Cd for the latest plantedcrops. Conversely, grain filling duration was shortest for the earliest or latest plantings (1220°Cd) vs. 1270°Cd for optimum plantingdates.

Roshan et al. (2013) studied present and future climate projections over the region ofwheat production over Iran. Observedclimate (temperature and degree day) changes during theperiod (1951–2009) is discussed andprojected futurechanges up to 2100 based on the MAGICC/SCENGEN 5.3compound model was utilized. It was concluded that the wheat growthperiod will be negatively affected due to the increase ofthe temperature. The growth period is expected to be shorterby 21.3, 22.3, 23.9, 26.7, and 32.3 days for the northern,western, central, southern, and eastern regions by the year 2050.

Andarzian et al. (2014) studied 4 stations in Khuzestan province, Iran to determine optimum sowing date using Cropping System Model (CSM)-CERES-Wheat model. Themodel was run for 8 sowing dates starting on 25 October and repeated every 10 days until 5 January. They assessed the performance of model based on different statistics anthesis date, maturity date, grain yield and biomass compared to observed data.

Waha et al. (2012) studied management measures for adaption to impacts of climate change in Sub-Saharan Africa, including dual cropping system of maize-groundnut and choice of optimal planting date. They suggested that even though cropping system modification can reduce negative impacts of climate change, but it requires knowledge, labor, enough time for soil preparation and market and also adds up the risk of facing non rainy seasons. Instead, farmers can adapt sowing date to the start of the mainrainy season, which has showed good results in Northern provinces of South Africa nad Cameron.

Dobor et al. (2016) strived to develop a mechanism to optimal choice of planting date. PD data from 294 agricultural enterprises in Hungary during the period from 2001 to2010 were used to validate the PD methods. Effect of climate change on the timing of PD was evaluatedusing an ensemble of 10 climate change projections. Their analysis predicts a shift to earlier PDs for maize (approx. 12 days) and laterPD for winter wheat (approx. 17 days) for the 2071–2100 period. The results indicated that maize PDsshould be changed according to the earlier start of the growing season in spring. In contrast, currentlyused PDs should be preserved for winter wheat to avoid climate change related yield loss. Proposed PD estimation methods performed better than other eight tested methods.

In a Mediterranean type environment the correct choice ofsowing date and cultivar are critical determinants of yield (Connoret al., 1992). Sowing date may normally occur within a ‘sowingwindow’ starting with the first significant rainfall after summerand closing when a sowing date would be too late to achieve areasonable yield. It is general practice in most Mediterraneanenvironments to sow at the beginning of the rainfall season inautumn if the frost risk for anthesis is low with such an earlysowing date. The advantages of this practice have been widelyshown through field experiments and crop simulation models(Stapper and Harris, 1989; Shackley and Anderson, 1995; Henget al., 2007; Asseng et al., 2008).

Early sowing dates increase theinterception of solar radiance of a crop, allowing it to accumulatemore dry matter (Stapper and Harris, 1989), and avoid terminal-drought at the end of the growing season. This practice isconsidered less feasible where frost risk during later winter/earlyspring is too high (Connor et al., 1992; Anderson et al., 1995), but ifappropriate cultivars are available, the risk of frost damage can beminimized (Stapper and Fischer, 1990).

In this article, adaptable planting date strategy is studied over cool temperate region of north-western Iran, affected by Mediterranean weather systems, using 8 scenarios beginning from 26 September, each with 7 days lag. The trend in four phenological stages beside total Length of Crop Season (LCS) as a measure of intensity of the effect of climate is calculated in 27 stations in the region.

MATERIALS ANDMETHODS

The field statistics shows us that almost 90% of farms in north-western Iran are planted in the first two months of autumn from 22 September to 20 November. As the meteorological conditions vary with yearly date, correct choice of planting date is a key factor to avoid threats in different growing stages of the plants and reach best quality and quantity of product. In this article, 27

FIGURE 1. The area of study and 27 stations selected

synoptic stations with complete data series available for 25 years from agricultural year 1989-90 to 2014-15 are studied. To show the effect of choice of planting date, 8 scenarios, each one with 7days additional lag, are designed for planting date, beginning from 26 September every year. Four reference phenological stages are selected based on GDD received in each stage in each year and the length of stage is calculated. A trends analysis is performed on each stage for each scenario. The absolute shift of trend in each stage and total trend existing in sum of length of stages as Length of Crop Season (LCS) is described as statistics showing vulnerability to climate change and summarized to show its behavior spatially and temporally.

The duration of the length of crop season (LCS) and of the crop development phases was simulated using the concept of growing degree days (GDD,°C day−1) adopting the approach described inRaes et al. (2012):

$$GDD = \begin{cases} \frac{T_{max} + T_{min}}{2} - T_{base} & ; if \ \frac{T_{max} + T_{min}}{2} > 0 \\ 0 & ; otherwise \end{cases} \qquad (1)$$

Where and are maximum and minimum air temperature,respectively, and T_{base} refers to the base temperature, considered equal to zero for winter wheat. The GDD required for achieving initial stage of growing of wheat is considered 400°C, for Anthesis stage equal to 1250°C, for Maturity stage 1900°C and finally the Harvest stage 2150°C, summing up from the planting date.

Calculating lengths of different stages for 27 selected stations in 25 years of studying period considering 8 different scenarios for planting date,results in 17024 figures. After that, statistics including mean, standard deviation, coefficient of variation of lengths of each period and trend (°C/year) and Pearson product moment are calculated for 648 states in 4 different stages of 8 mentioned scenarios.The Length of Crop Season is the sum of lengths of 4 stages of growth mentioned.

$$LCS = L_{initial} + L_{Anthesis} + L_{Maturity} + L_{Harvest} \qquad (2)$$

So the total trend observed in LCS is also equal to sum of trends observed in each growing stage. Dependency of Lengths of each period besides the total LCS is studied. Whether the trend of the length of each period is related to selection of planting date is determined as the measure of effect of date of planting scenario choice on vulnerability to climate change.

RESULTS AND DISCUSSION

Assuming choice of a specific scenario and averaging resulted LCSs for each station, we observe a possible.

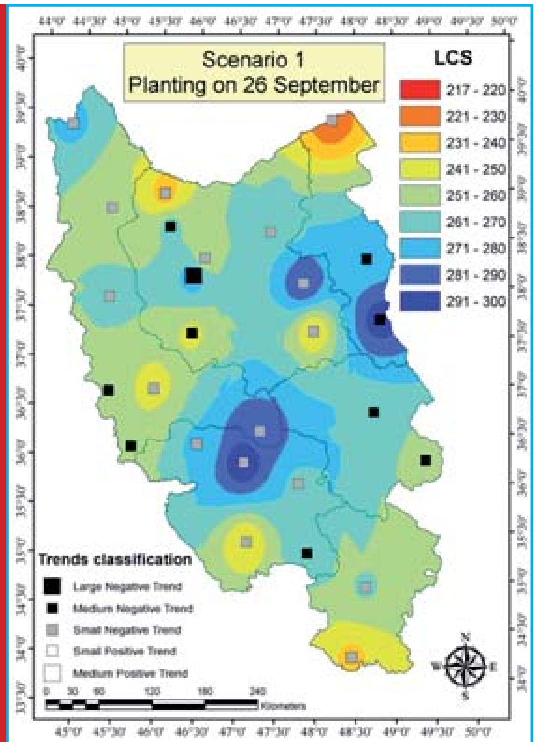

FIGURE 2. LCS and its trend according to Scenario 1

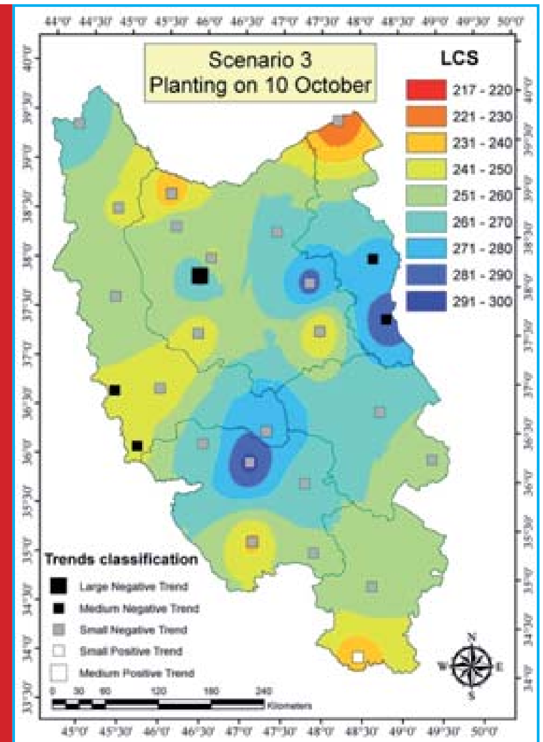

FIGURE 4. LCS and its trend according to Scenario 3

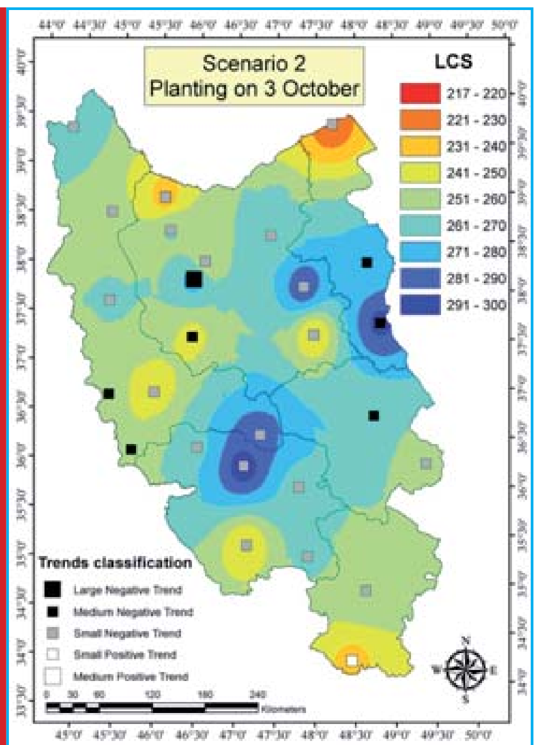

FIGURE 3. LCS and its trend according to Scenaio 2

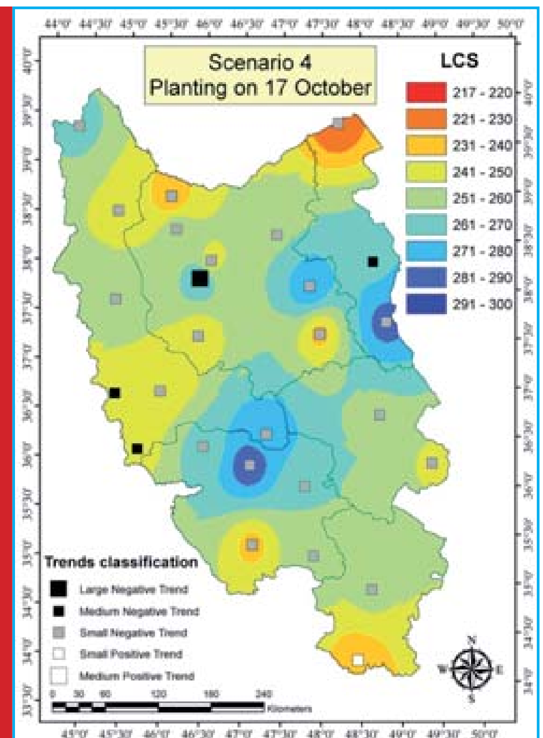

FIGURE 5. LCS and its trend according to Scenario 4

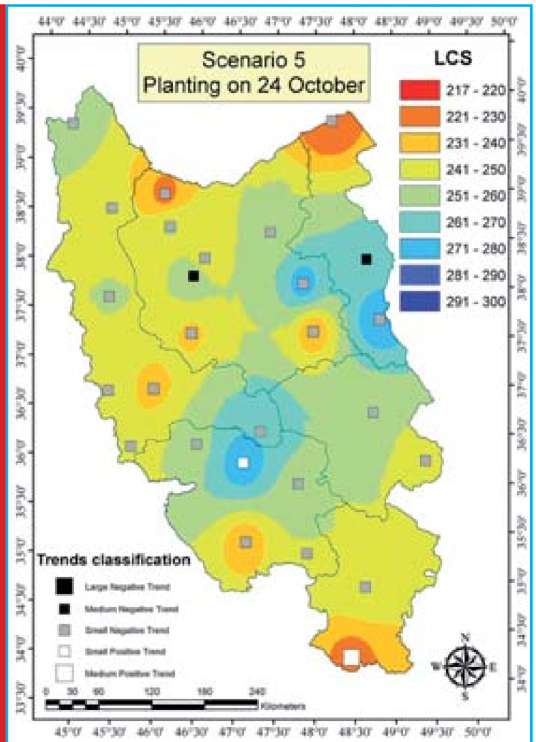

FIGURE 6. LCS and its trend according to Scenario 5

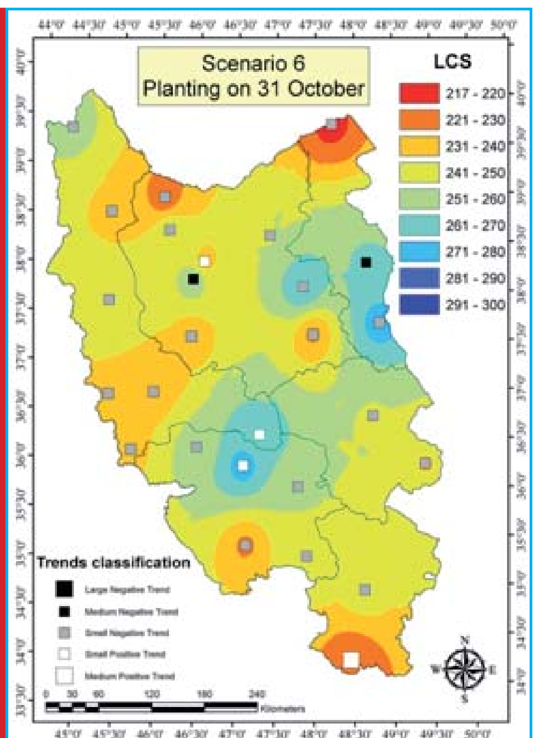

FIGURE 7. LCS and its trend according to Scenario 6

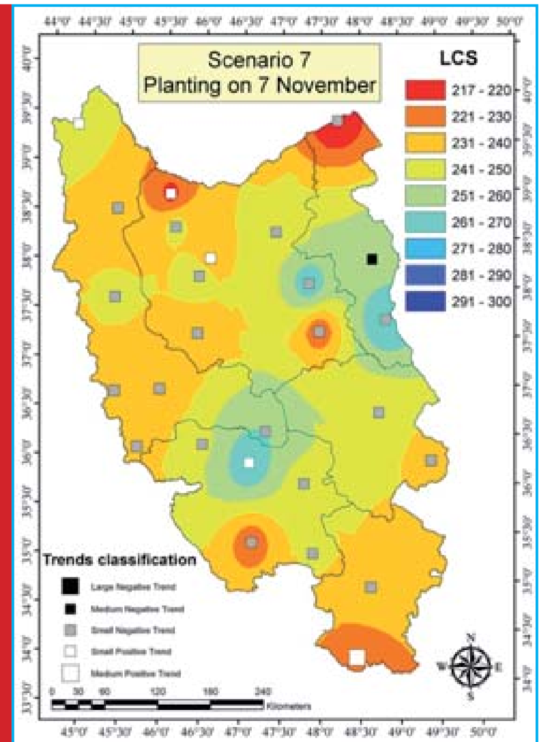

FIGURE 8. LCS and its trend according to Scenario 7

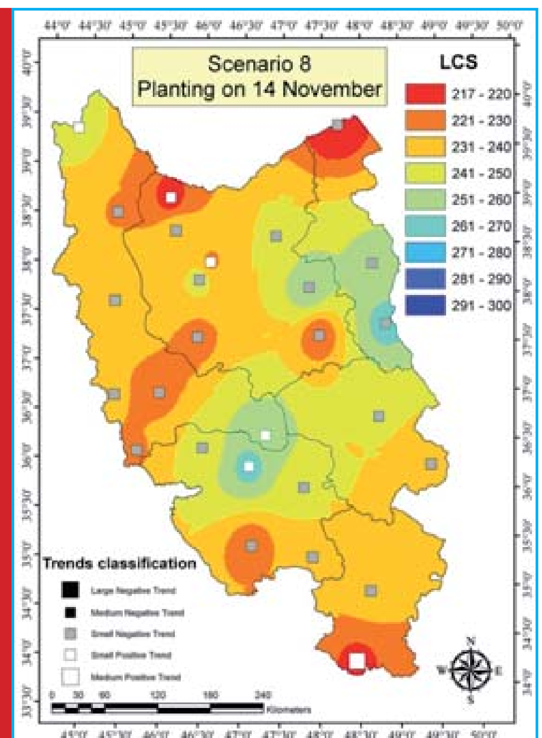

FIGURE 9. LCS and its trend according to Scenario 8

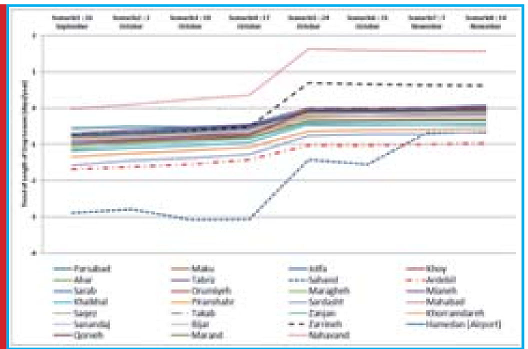

CHART 1. Change of observed trend in LCS with changed scenario of planting date in 27 selected stations

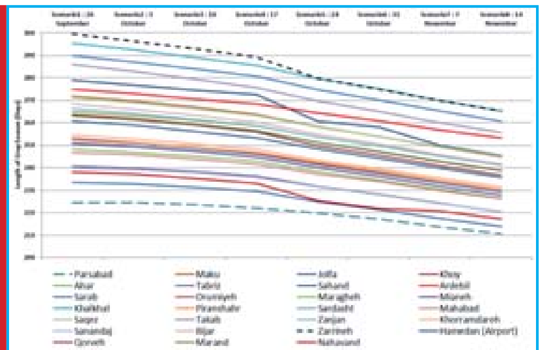

CHART 2. Length of mean crop season according to each scenario on 27 selected stations

Whether or not the trend is meaningful can be tested statistically but is beyond the scope of this article. Here we classify trends below -2days/year as classified as "Large negative trend" implying rapid (and even obvious) shrinking of LCS period. Other trends below -1 are classified as Medium Negative, below 0 as "Small negative', below +0.7 as "small positive" and below 1.6 as "Medium positive". The more negative the trend, the more shrinking of LCS which inherently results in

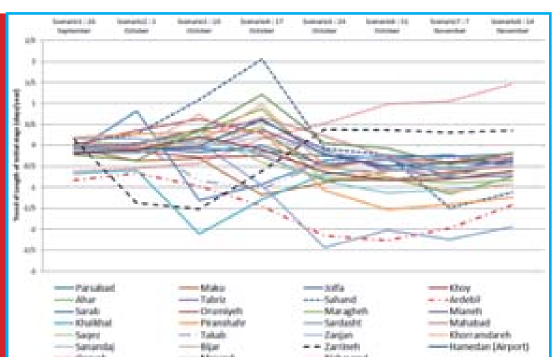

CHART 3. As in Chart 1 for initial stage

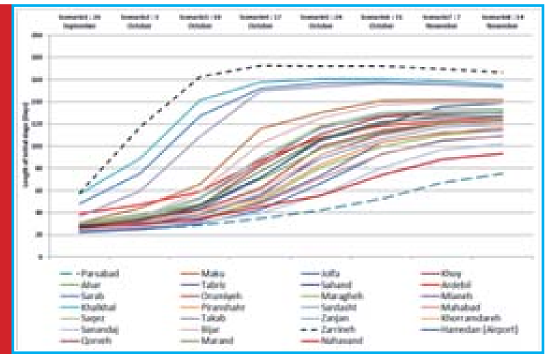

CHART 4. As in Chart 2 for initial stage

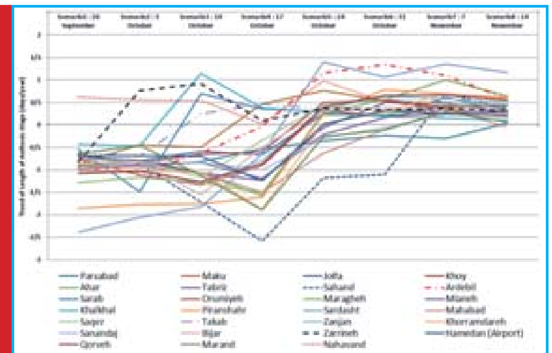

CHART 5. As in Chart 1 for Anthesis stage

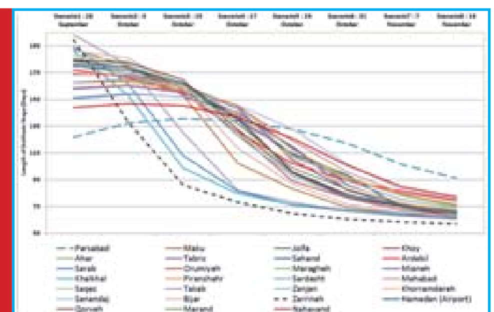

CHART 6. As in Chart 2 for Antesis stage

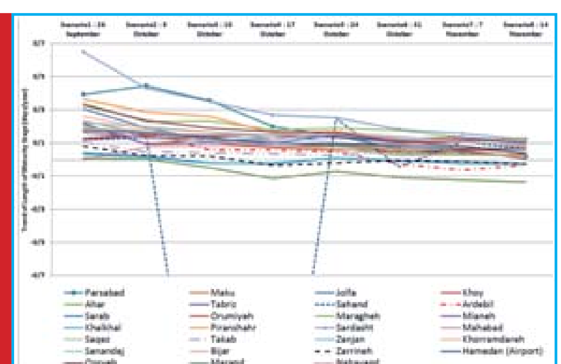

CHART 7. As in Chart 1 for Maturity stage

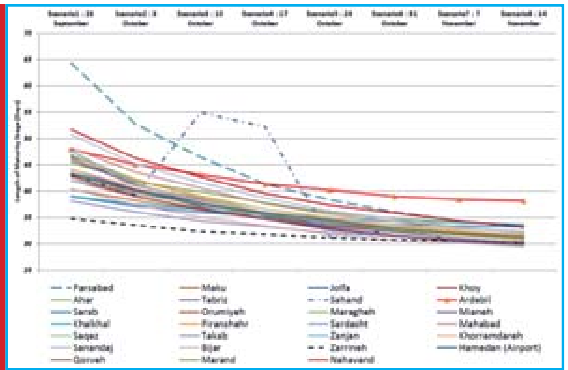

CHART 8. As in chart 2 for Maturity stage

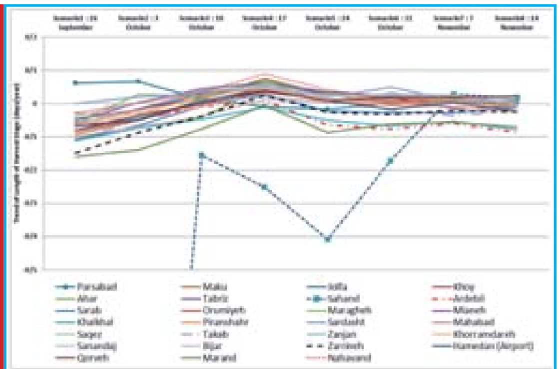

CHART 9. As in Chart 1 for Harvest Stage

less available sun hours and less quality and yield. This can be avoided by better choice of planting date if this selection results in smaller absolute observed trend and therefore, more stable conditions climatically.

The obvious shortening of LCS with adding lag to planting date scenario which is aunfavorable result, despite the other obvious finding that the trends are damped when adding to planting date lag scenario which seems to be a favorable one.

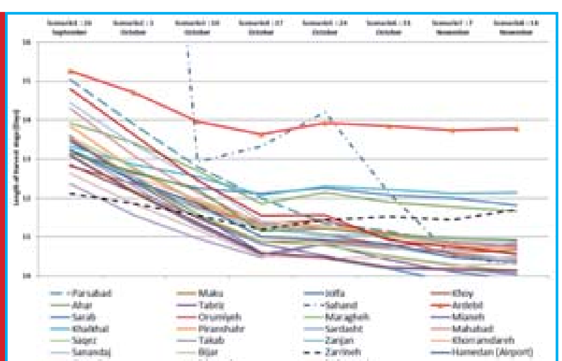

CHART 10. As in Chart 2 for Harvest Stage

As the chart 1 shows, all stations face positive change in trend of LCS when adding to scenario date. Ardebil station is least affected and Sahand station the most. Nahavand station has positive trend and reaches the maximum value. Also Zarrineh station showed a shift from negative to positive trend on scenario4 (planting on 17October). Almost all other stations move toward zero trend when choosing scenario 5 to 8. Also the mean observed LCS is lowered between 15 days in Parsabad station to 35 days in Zarrineh station when postponing the planting date.

This result is the sum of effect on phonological growing stages. Similar analysis on stages is performed and results are depicted on charts.

Initial stage of growth shows completely different results for different stations. Nahavand station shows a constant increase with adding to lag scenario. It moves from -0.5 negative trend to +1.5 days/year. For Sarab, Khalkhal and Zarrineh stations, trend becomes large negative in first scenarios and diminishes in scenarios 5 to 8. Sardasht, Ardebil and Piranshahr stations show a constant move toward large negative trends. The other stations, begin from zero trend, reach a maximum positive trend on scenario4 (17 October) and continue to medium negative trends on scenarios 5 to 8.

Also the mean observed Length of initial stage is added between 50 (in Parsabad station) to 110 days (in Zarrineh station) when postponing the planting date.

Trend existing in the length of Anthesis stage also shows different behavior in different stations. Some of stations, very cold in climate, show a peak in first planting scenarios like Zarrineh, Khalkhal, Sarab. They reach near zero trend in this stage for last scenarios of planting. Some other stations like Sardasht, Ardebil, Piranshahr and Maragheh reach their peak in last scenarios showing a maximum positive trend there, meaning sharp elongation of length ofanthesis stage if planting is postponed a lot. Others show a minimum trend on scenario 4 and reach near zero trend on last stages. Among these, Sahand station shows maximum descent, obviously more than other stations. Totally, adding to trend for all stations when selecting late planting scenario can be confirmed visually. Also the mean observed Length of Anthesis stage lowered between 40 days in Parsabad station to 120 days in Zarrineh, Bijarand Takabstation when postponing the planting date.

The mean observed Length of Maturity stage lowers between 30 days in Parsabad station to 5 days in Zarrineh station when postponing the planting date. Sahand station shows a peak on scenario 3 but returns to normal situation on last scenarios. It can be said that except Ardebil station that remains indifferent to selection of planting scenario, all stations converge to about

32 days in late scenarios and totally, less vulnerability is observed to planting date selection. The same condition is obvious in trends chart with maximum descent of trend in Parsabad and Sardasht stations and near zero trend in late scenarios.

The mean observed Length of Harvest stage lowers between 4 days in Parsabad station to 5 days in Zarrineh and Takab stations when postponing the planting date. Sahand station shows a different sharply descending behavior but returns to normal situation on last scenarios. It can be said that except Ardebil station that remains indifferent to selection of planting scenario, all stations converge to about 11 days in late scenarios and totally, less vulnerability is observed to planting date selection. The same condition is obvious in trends chart with maximum descent of trend in Parsabad and Ascent in Maragheh and Zarrineh stations and near zero trend in late scenarios.

CONCLUSION

In this article, 27 stations in 6 north-western provinces of Iran, which are prone of cultivating winter wheat, are studied. The magnitude of observed trend in 4 phenological stages (Initial, Anthesis, Maturity and Harvest) are calculated based on required Growing Degree Days on 25 years period from Crop Season of year 1989-90 to 2014-15 according to 8 planting date scenarios beginning from 26 September with 7 days lag between scenarios.

The results show that Anthesis stage is most vulnerable to climate change. Initial stage is in second rank and the last stages of maturity and harvest seems to be indifferent to planting date choice. The trend in total Length of Crop Serason (LCS) becomes more positive when postponing planting date. This implies diminishing of negative trend in case of planting on 26 September, except of Nahavand station that faces a positive trend in late planting scenarios and Zarrineh station that shift sign of trend on scenario 4. Even though this finding shows more stable conditions if late planting is chosen, obvious decrease in total crop length season for all stations, which is negative in the sense that it means shorter photoperiod, less quality/quantity product and also adding the risk of facing frost in Anthesis stage, planting in October is suggested to be better.

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