

Delineating Efficient Cropping Zones of Potato and Chilli in Tamilnadu

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Authors' contributions

This work was carried out in collaboration between both authors. Author TS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author NK performed the statistical analysis and managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Potato and Chilli are the most significant horticultural vegetable crops commercially cultivated in both field level and homestead gardening. India is leading producer of chilli and 2nd leading of potato in the world, but inadequate storage and huge unpredictable weather conditions leads to losses. This study was done to analyse trend changes in area, production and productivity over 30 years study period (1985-2015) and also identify Efficient Cropping zones of potato and chillies, at district level for Tamil Nadu during 2000-2015, in order to venture the hotspots of 21st century. Results of trend analysis revealed that potato production was decreasing till early 21st century and thereafter increasing gradually with respect to cropping area and chilli showed reduction in production over the years. Relative Yield Index (RYI) and Relative Spread Index (RSI) were used to figure out potential cropping districts for both crops over Tamil Nadu. Dindigul, Erode and Krishnagiri districts were found to be efficient cropping zone, while Nilgiris is sole district of Most Efficient Cropping Zone (MECZ) for potato. Virudhunagar district has been the Most Efficient Cropping Zone for chilli crop, while Ramanathapuram, Sivagangai, Tirunelveli, and Thoothukkudi districts were identified as potential efficient zone (ECZs) in Tamil Nadu. Hence, this paper attempts to identify the hotspot area and to study the deviation in cultivable land, production and

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productivity of the crops where farmers are facing most of the problems. The climate change scenarios could influence crop cultivation, and this paper is evident on the changes in efficient cropping zones.

Keywords: *Potato; chilli; Relative Spread Index (RSI); Relative Yield Index (RYI); efficient cropping zones.*

1. INTRODUCTION

Agriculture sector is undergoing distinguishable changes by adopting modern innovation techniques from traditional followings which is an important push by government sectors on doubling farmer's income. India is one among the scarce countries, dwindling with an average per capita availability from 0.209 (1985) to 0.118 ha (2016), however Indian horticultural crops are fetching 20–30 times more foreign exchange values per unit area than agricultural crops, where the horticultural sector of Tamil Nadu state is overriding for enhancing the economy growth (world bank data) [1]. Vegetables have been an integral part of our daily dietary requirements where, very vegetable is unique with its composition of vitamins, minerals, fibre and even water content that is essential for the human body. This paper discusses about the most preferred vegetable crop around the world, namely potato and a culinary crop – chilli which is a vegetable in fresh form and a spice when dried. Surprisingly, both are *Solanaceous* crops with different characteristics, growth conditions and climatological preferences. Potato is a tuber crop and chilli is a fruit bearer, but both rule the food industry.

Potato is a highly versatile vegetable crop, often called as “The King of Vegetables” and poor man's friend, being 3rd most important consuming food crop after wheat and rice. Being much incredible in accommodating and adaptability, potato crop modified consumption habits of Indians and, there is a fast shift observed over the years in consumption of potato which urges the farmers cultivating potato to fulfil the needs of growing population. Hence, the production was increasing enormously in last decade at an average of 46.39 million tonnes from 2.024 million hectares in Indian sub-continent and in Tamil Nadu it was 1.16 lakhs tonnes from 5,350 hectares during 2013-14. This was an increase of 35 per cent and 34 per cent respectively in production and area, when compared to the previous year where climate played a vital contribution in cultivation over Indian cropping patterns. Detailed analysis in

potato production showed that area, production and productivity considerably increased recent past with all the states in India except Uttar Pradesh [2].

Potato cultivation in India is mainly practised over hilly regions and most of the small-scale farmers are growing potatoes for self-consumption, rather than as a business. Also, input factors such as intensive capital, fertilizers and agrochemicals are expensive which determines the cultivation aspects of a particular region. Potatoes are mostly produced in low productive regions with soil problems. So, farmers tend to use inferior quality inputs, particularly inferior potato seeds [3].

Chillies (red pepper, wonder spice) was first discovered and domesticated spice crop in American continent, called as universal spice crop famous for their dark colour and high pungency levels which rule every household kitchen in the world. Chilli is produced globally around 7 million tonnes from cultivated area of 1.5 million hectares of land. India is the world leader in chilli production (ranges from 50 to 60 per cent) followed by China and Pakistan. Andhra Pradesh is positioning top in production and export of chillies followed by Karnataka, Odisha, Tamil Nadu and Maharashtra [4]. These states are contributing towards nearly 75 per cent of the national production and who had contributed an economy value of around 150 billion Indian rupees in fiscal year 2015 which is higher than the previous years. Tamil Nadu is one of the potential chillies producing states, contributing 8 per cent out on national terms and famous for Ramanathapuram mundu, sattur samba varieties. Though chilli is a dry tract ruler in Tamilnadu as a spice, other districts prefer to grow the crop as vegetable green chilli. But there are few constraints for farmers to enhance the crop productivity even when this crop is economically beneficial. From the analysis, it is confirmed that chilli growers need to be educated regarding the use of treated seeds, maintaining correct spacing and irrigating the crop at the recommended intervals [5].

Several studies have used RSI and RYI to identify efficient crop zones of various crops in Tamil Nadu, viz. rice, sorghum, black gram, cotton, sugarcane [6,7], pearl millet, red gram, green gram, chick pea, horse gram [8], and efficient cropping zones for groundnut in Tamil Nadu [9]. But Efficient Cropping Zones of horticultural crops is still an exploration to be taken up by researchers and this paper determines to identify the hotspots of potato and chilli crops along with their zonal shift towards cropping.

2. METHODOLOGY

2.1 Study Area

The study was carried out over Tamil Nadu state, India to identify the Efficient Cropping Zone (ECZ) and analysing the trend changes with respect to area, production and productivity for potato and chillies crops. Tamil Nadu, state of India, located in the extreme south of the subcontinent. It is bounded by the Indian Ocean to the east and south and by the states of Kerala to the west, Karnataka (formerly Mysore) to the northwest, and Andhra Pradesh to the north.

2.2 Data

The districts and state data of area, production and productivity for 30 years (1985-

2015) and total cultivable area of Tamil Nadu for 15 years (2000-2015) were collected from crop production statistics information system and respective season and crop reports (SCR) [10].

2.3 Trend Analysis

The trend analysis of area, production and productivity was done, and the trend line was plotted by using given below formula

$$Y_t = abt e^{ut}$$

Where,

- Y_t = Dependent variable in period t (Area/ Production/ Productivity)
- a = Intercept
- b = Regression coefficient= (1+g)
- t = Years which takes values, 1, 2, ..., n
- ut = Disturbance term for the year t

2.4 Efficient Cropping Zone

Efficient Cropping Zones were identified based on temporal database of area and production for various districts in Tamil Nadu; RSI(Relative Spread Index) and RYI (Relative Yield Index) were calculated as 5 years average.

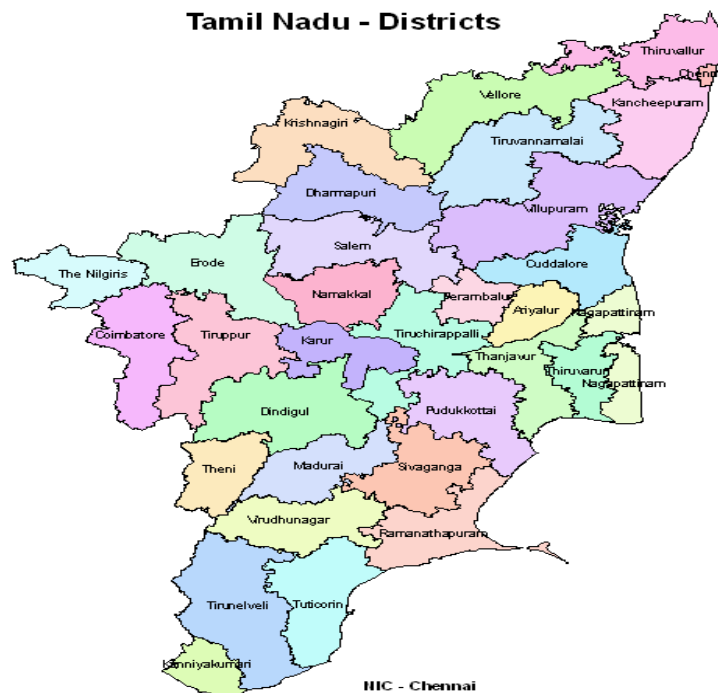


Fig. 1. Districts map of Tamil Nadu used during the study period (2001-2015)

Statistical computation formulae used in this study to calculate Relative Yield Index (RYI) and Relative Spread Index (RSI) and criteria for classification of Efficient Cropping Zone (ECZ) are given as follows [11] and [9].

$$RSI = \frac{\text{Area of particular crop expressed as \% of total cultivable area in the district}}{\text{Area of crop expressed as percentage to the total cultivable area in the State}} * 100$$

$$RYI = \frac{\text{Mean yield of a particular crop in a district (Kg/ha)}}{\text{Mean yield of the crop in the State (Kg/ha)}} * 100$$

Table 1. Criteria for classification of ECZ

RSI	RYI	Cropping Zone
>100 (High)	>100 (High)	Most Efficient Cropping Zone (MECZ)
>100 (High)	< 100 (Low)	Efficient Cropping Zone (ECZ)
< 100 (Low)	>100 (High)	Not Efficient Cropping Zone (NECZ)
< 100 (Low)	< 100 (Low)	Highly Inefficient Cropping Zone (HICZ)

2.5 Mapping

ArcGIS v10.5 was used to map the district level Efficient Cropping Zones of Potato and Chilli crops over Tamilnadu state. The maps were created for the 5 years average time periods and compared with the base period (1995-2000) to understand the shift of cropping zones. An average map for the 15 years study period (2001-2015) was also created.

3. RESULTS AND DISCUSSION

3.1 Trend Analysis

Trend analysis on potato crop revealed that the average, production and productivity during 1985-2015 study period over Tamil Nadu are 5469 ha, 1 lakh tonnes and 18,902 kg/ha respectively. Production of potato followed the same trend as the changes in cultivated area whereas productivity was followed the same trend as the cultivable area during the starting of study period and thereafter showed an increasing trend till 1997-1998 (Fig. 2) and highest rate of economic yield was obtained during 1987-88 period and thereafter production showed a decreasing trend with respect to reduction in area till 1995-1996. The trend was confirmed by the study of Singh and Rana, 2014. In their work, they did mention that potato cultivation in India was restricted in late 18th to early 19th century which continued till 1941. They have narrated the reason behind the production restriction owing to the unsuitability of long day condition varieties cultivated under short day Indian conditions. During recent past, production and harvested area of potato firmly increased after 1996-1997 and showed a milder growth in

productivity during 2014-2015. The trend change was confirmed from the study conducted by FAOSTAT, where the tremendous increase of production might be as a result of introducing Seed Plot Technique by CPRI, which provides 30-40% higher yields in potato cultivation [12].

For chilli crop, the average area, production and productivity (1985-2015) over Tamil Nadu were 64.2 '000 ha, 36.9 '000 tonnes and 0.6 tonnes/ha respectively. Production fluctuated in the aspect of cropped area and the highest rate of fluctuations were observed between 1995 and 2001, thereafter it had showed a decreasing trend. It was observed that the rate of production and productivity decreased drastically during 2010-2011, the crop was damaged by unseasonal El-Nino conditions over India and potential yield was increased thereafter till end of the study period (Fig. 3). The result was confirmed from chilli productivity deviation study by Kowshika et al. [13]. Also, year to year reduction in yield of chilli was observed in this study, which could be due to technology gap for production as well as marketing. It was confirmed by Balraj and Arockiasamy [14], who stated that cultivated area of chilli in Ramanathapuram, the major chilli growing district is showing a decreasing trend over the years.

The trend in Production of potato over Tamil Nadu (1985-2015) revealed that during 51-75 per cent of the years, production had been 1.0 – 1.4 lakh tonnes, whilst 25-50 per cent years gave 0.8 – 1.0 lakh tonnes (Fig. 4). Chilli production trend for the same time period was observed to be 37.5 – 43.9 thousand tonnes for 51 – 75 per cent of the years and 25 – 50 per cent of the years resulted in 29.9 – 37.5 thousand tonnes (Fig. 5).

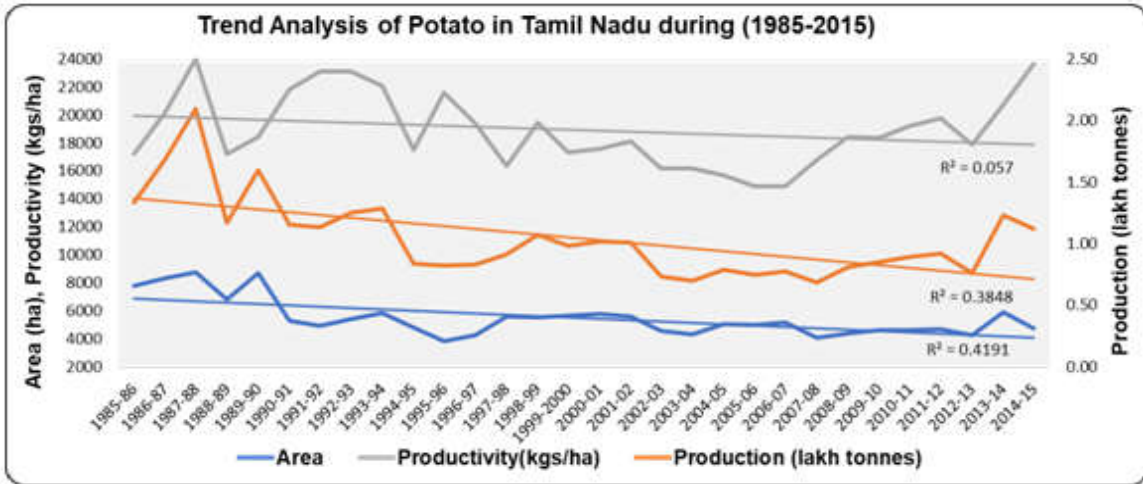


Fig. 2. Trend of area, production and productivity of potato in Tamil Nadu (1985-2015)

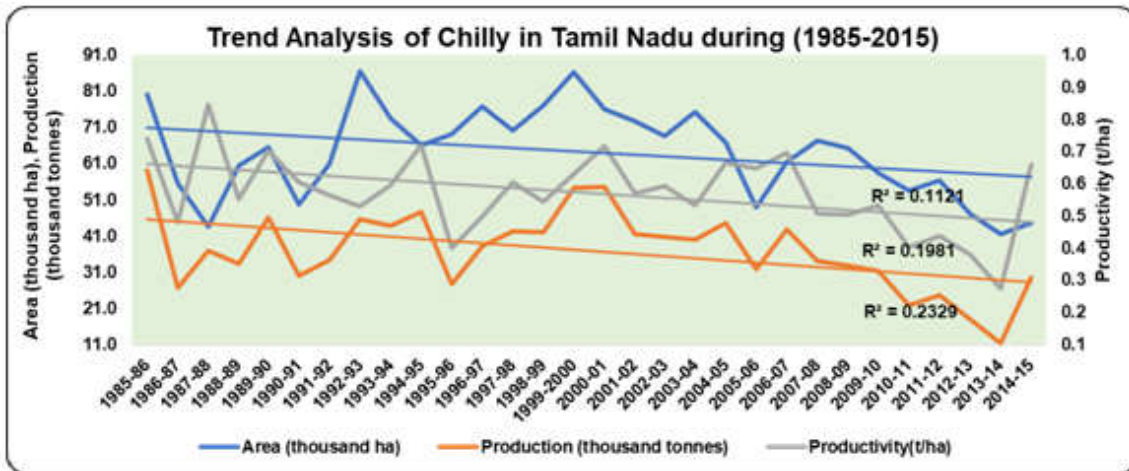


Fig. 3. Trend of area, production and productivity of chillies in Tamil Nadu during (1985-2015)

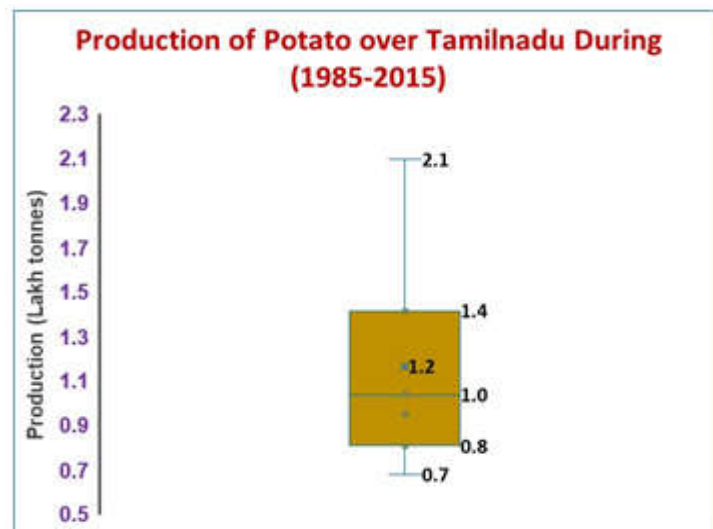


Fig. 4. Production of potato over Tamil Nadu (1985-2015)

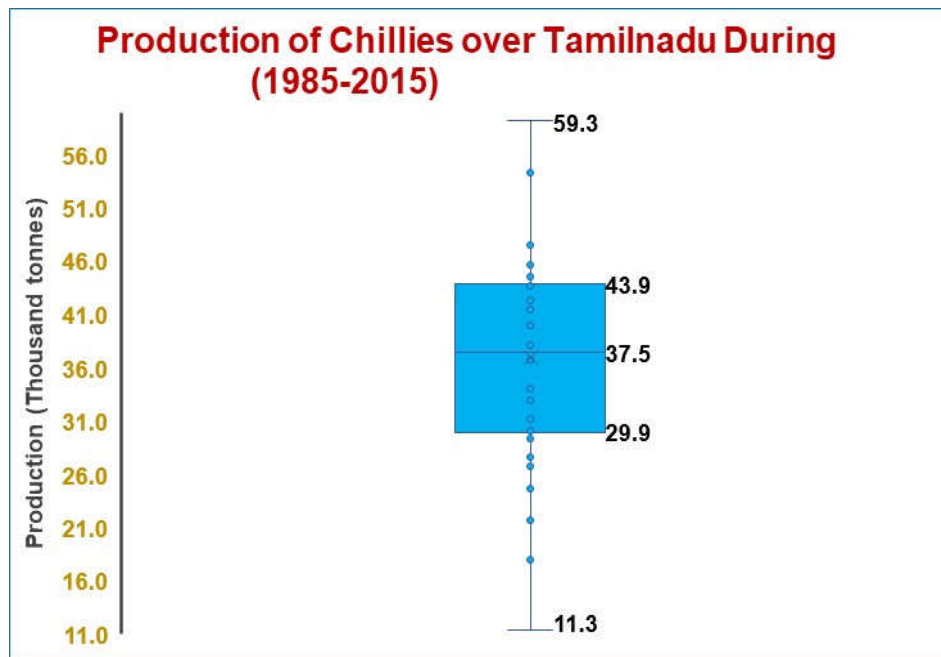


Fig. 5. Production of chillies over Tamil Nadu (1985-2015)

3.2 Efficient Cropping Zone (ECZ)

The availability of suitable soil and climate makes a particular crop perform well to produce more economic yield than other regions claiming it to be an efficient zone. With respect to efficient cropping zone (ECZ), it has a higher Relative Spread Index (RSI) along with higher Relative Yield Index (RYI). In Tamil Nadu, RSI is determined by inputs such as seeds, fertilizers, water, pesticides, availability of labour, technology, Government policies etc., whereas, RYI is determined by the climate of the particular domain along with prevailing weather within that climate [15].

3.2.1 Potato

Efficient Cropping Zone analysis for Potato crop revealed that Nilgiris, Dindigul, Erode and Krishnagiri districts found to be potential hotspot areas among districts of Tamil Nadu when considering RYI and RSI (Fig. 6a-6d). Though potato is a cool season crop and is cultivated at hilly regions in Tamil Nadu, cultivating trend is shifting over to few plain regions. The trend in cultivation of potato is expanding into North-Western Zone districts such as Krishnagiri and Erode since 2003 onwards, where farmers are contributing their interest in producing potato. During the base period (1995-2000) potato cultivation has been found in the districts of Dindigul and Nilgiris being Efficient Cropping

Zones (ECZs), but Krishnagiri and Erode districts have ventured into this trend on the later study period. Krishnagiri district has been a MECZ between 2005 and 2015, while the average performance for 15 years study period still classifies it as ECZ. Contradictorily, Erode district has upgraded to ECZ during 2010-2015, but still falling under HECZ on the average. This upgradation of Erode in the last five years of study into ECZ can be taken up as a benefit. However, Nilgiris still owns the proprietorship of MECZ during the entire study period of 15 years (Fig. 7).

3.2.2 Chilli

Chilli is always a benevolent crop of Southern Zone districts. The base period (1995-2000) study of chilli crop reveals that the crop is Most Efficiently Cropped in Thiruvallur, Virudhunagar and Thirunelveli districts, while Karur, Perambalur, Ramanathapuram, Sivagangai and Thoothukkudi districts have been ECZs (Fig. 8a).

In the 15 years study period (2001-2015) of Chilli crop, Southern districts such as Ramanathapuram, Virudhunagar, Sivagangai, Tirunelveli, and Thoothukkudi districts are found to be efficient cropping zones (Fig. 8b-8d). Virudhunagar district is determined to hold the position as Most Efficient Cropping Zone both in the base period and the study period, where Ramanathapuram, Sivagangai and Thoothukkudi

districts have been ECZs on both the time scales. The productivity index classification analysis done by Kowshika et al. [13] also had a relatable outcome, where Virudhunagar was highly productive. Jayam, and Murugesan, [16] found similar kind of result in their study that Ramanathapuram district contributed 31 per cent in state's chilli production, maintaining to be ECZ. There had been hardships for Thirunelveli, Karur and Perambalur disticts for dropping into NECZs

during the study period, from the level of ECZs on the base period which is evident on their lacuna. Since, chilli is an important spice and vegetable crop, it is cultivated in almost all the districts of Tamil Nadu. The districts Thiruvavur and Kanniyakumari showed the less potential to produce chilli, the reduction might be due to reduction of the cultivable area affected by several climate change scenarios (Fig. 9).

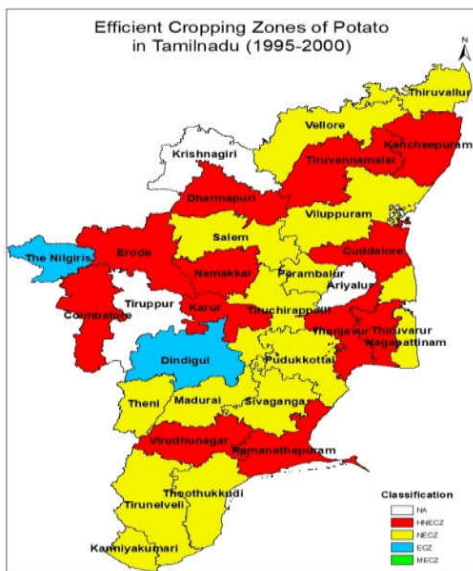


Fig. 6a. Efficient cropping zones of potato in Tamil Nadu (1995-2000)

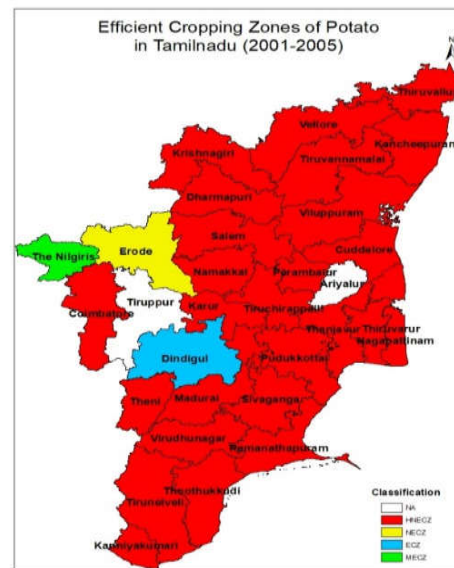


Fig. 6b. Efficient cropping zones of potato in Tamil Nadu (2001-2005)

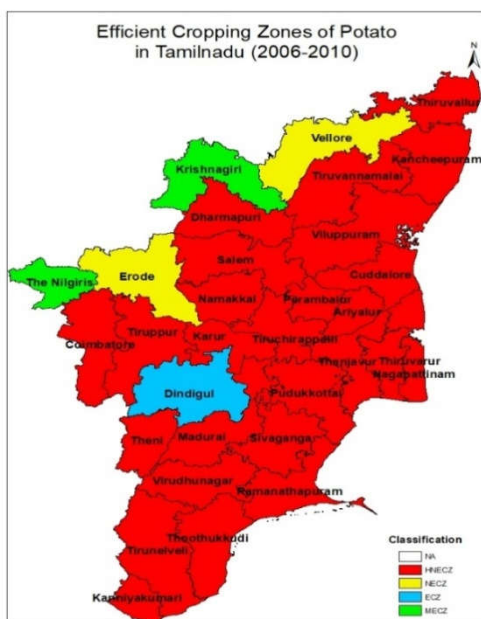


Fig. 6c. Efficient cropping zones of potato in Tamil Nadu (2006-2010)

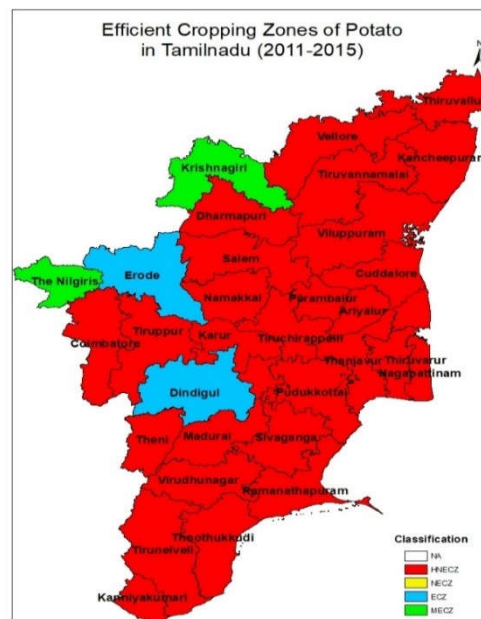


Fig. 6d. Efficient cropping zones of potato in Tamil Nadu (2011-2015)

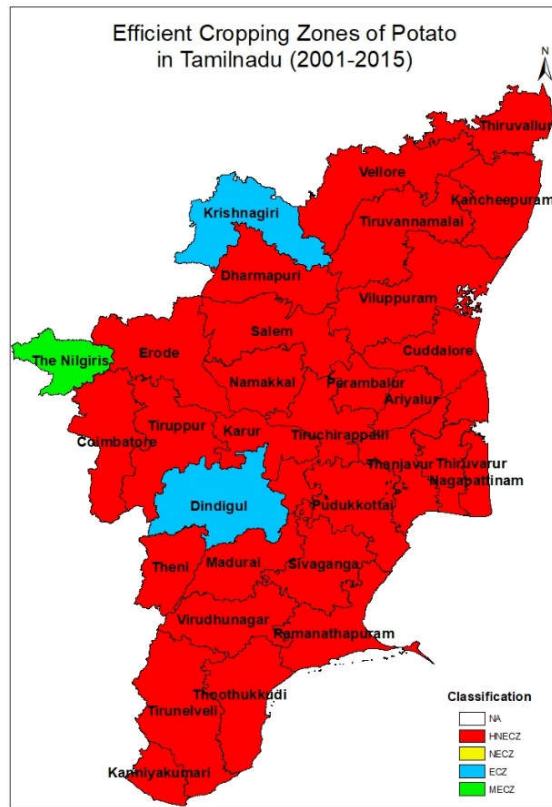


Fig. 7. Efficient cropping zones of potato in Tamil Nadu during overall study period (2001-2015)

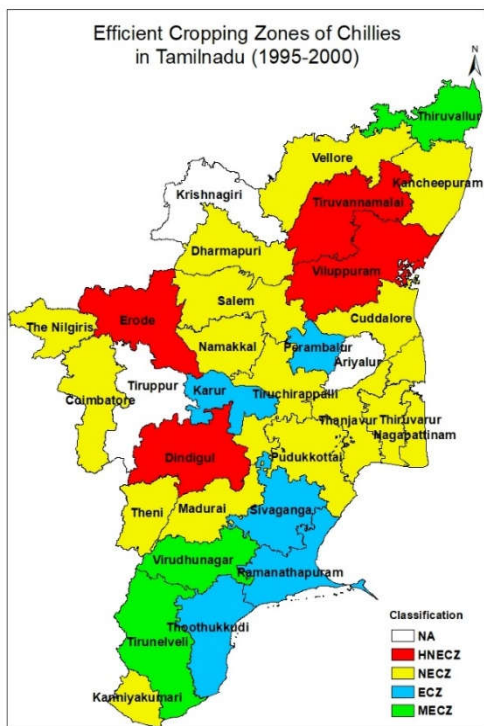


Fig. 8a. Efficient cropping zones of chillies in Tamil Nadu (1995-2000)

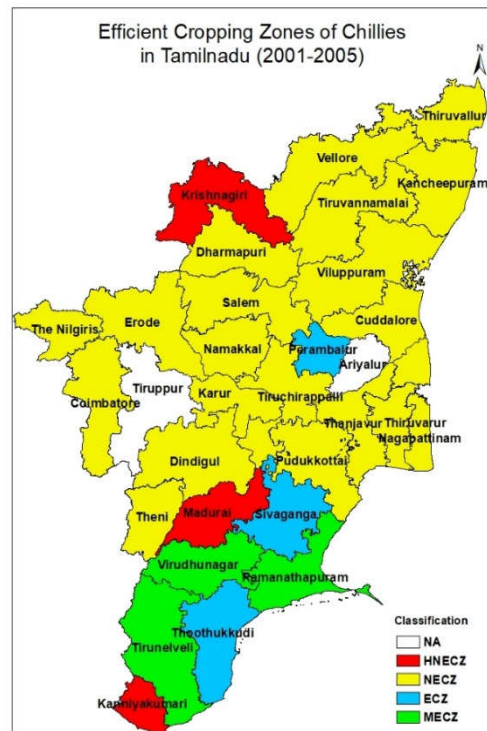


Fig. 8b. Efficient cropping zones of chillies in Tamil Nadu (2001-2005)

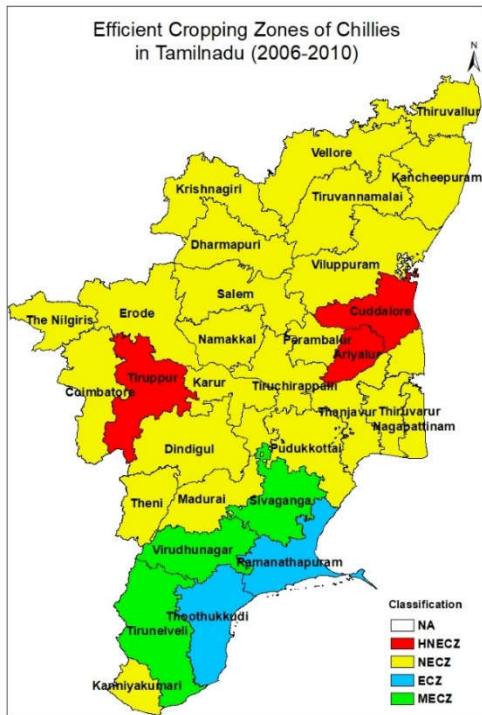


Fig. 8c. Efficient cropping zones of chillies in Tamil Nadu (2006-2010)

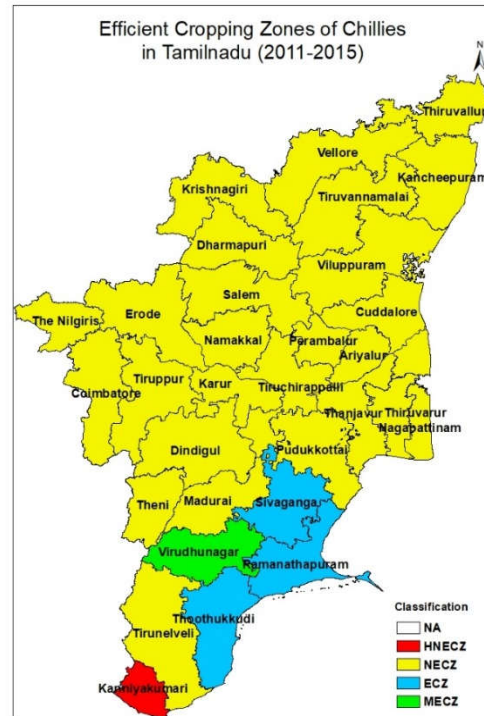


Fig. 8d. Efficient cropping zones of chillies in Tamil Nadu (2011-2015)

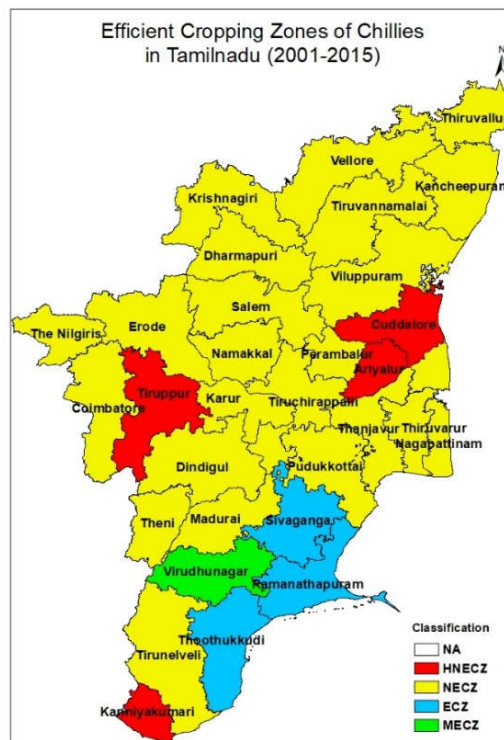


Fig. 9. Efficient cropping zones of chillies in Tamil Nadu during overall study period (2001-2015)

3.3 Effect of Climate Variability on MECZ Districts

3.3.1 Climate Variability on Nilgiris district

The annual rainfall of Nilgiris district which is the MECZ for potato crop shows an increasing trend (Fig. 10), while the annual maximum temperature is slightly increasing. Contradictorily the annual minimum temperature holds a slight decreasing trend, which could be beneficial for a crop like potato that needs to achieve the required temperature for flowering and tuber initiation. However, the level of increasing rainfall could pose grimace effects on potato crop if it coincides with the cropping season.

3.3.2 Climate variability on Viruthunagar district

From the Fig. 11, it could be observed that the annual rainfall and minimum temperature are undergoing an increasing trend, while the maximum temperature follows a slight decreasing trend. The increasing rainfall in Southern districts like Virudhunagar, which is a MECZ of chilli production, is surely to benefit in future. Meanwhile the drop in maximum temperature could save the crop from flower dropping conditions and the rainfall could support this. Since, chilli is a predominant dry land crop, increase in minimum temperature would enhance the metabolism to slighter scales.

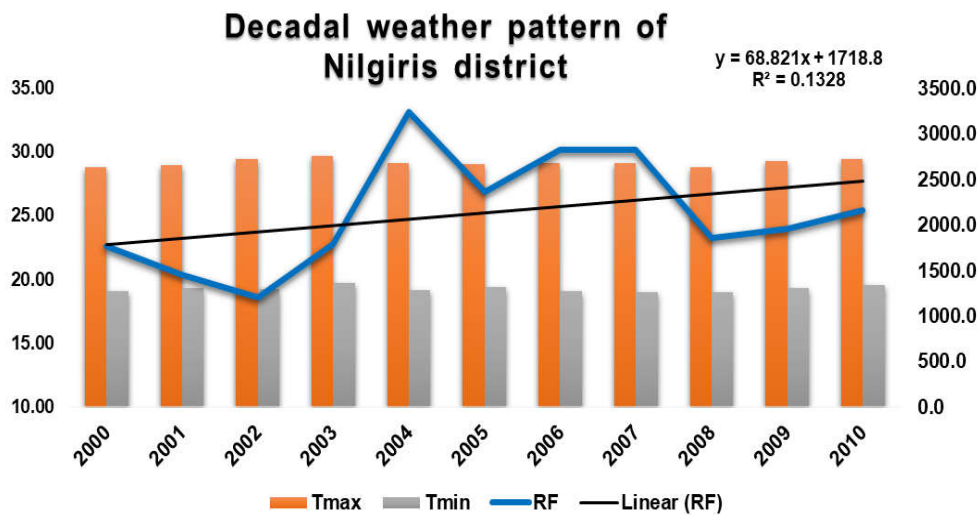


Fig. 10. Climate variability on Nilgiris district of Tamil naDu

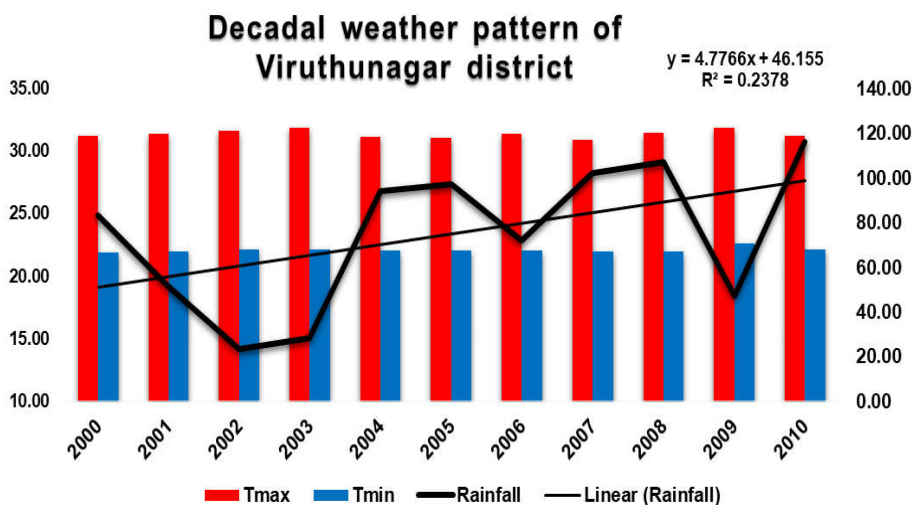


Fig. 11. Climate variability on Viruthunagar district of Tamil Nadu

4. CONCLUSION

Potato and chillies are wonder vegetables on the Indian culinary table. Many value-added products can be prepared by using potato viz., roasted, boiled, fried, baked, steamed forms or mostly in curry form. Besides, potato is also used for making starch (farina), alcohol, dextrin, and glucose and chilli is needed for daily diet as well as raw material to agricultural-based food processing industries. Farmers are facing difficulty in exporting potato and chilli at good quality which is lost due to improper storage. Potato is semi-perishable, and the bright red colour of chilli is reduced when it is stored at environmental temperature and drying it in the sun for prolonged period of time.

The present concept of trend analysis in area, production, productivity, and delineation of efficient cropping zone for most valuable horticultural vegetable crops *i.e.*, potato and chilli crop concluded the spreading of cultivable area is switching over to various parts of Tamil Nadu due to climate change and familiarity of crop by farmers. Potato crop had determined Nilgiris district as the Most Efficient Cropping Zone, while Krishnagiri and Erode districts have recently joined the ECZs. Chilli had a different performance, where the drier tracts of Virudhunagar district was MECZ and Ramanathapuram, Sivagangai and Thoothukkudi districts are ECZs. Both the crops are different in growth conditions, though hailing from the same Solanaceous family. Potato is a hilly area crop that is spreading towards plains, whereas chilli crop benefits the rainfed areas. Changes in their ECZs is vital to be identified for the policy makers for Sustainability in production and plan towards storage facilities near the MECZs and ECZs. This study would give an insight for the researchers and stakeholders to use the natural resources efficiently and to fix the subsidy rates for the identified crops so that farmers can get the high rate of returns over reduced expenditure. Hence, new technologies have to be developed to improve cropping patterns and production strategies as well.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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