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Assessing the impact of minimum temperature on crop over Winter season in northwest mountain areas of Vietnam

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Abstract. This report shows the method for assessing minimum temperature effecting on probability of plant growth over the winter in the northwest mountain region of Vietnam by useing Gumbel distribution. This method determines the beginning and ending of critical temperature threholds based on ENSO scenarios. Thence, safe periods are defined for plant in the research region. The results show that: In El Nino year, safe period is longer than in La Nina year.
Keywords: Minimum temperature, Critical temperature threshold, beginning and ending date of $T_n<T_c$, safety day.

1. Introduction

In agricultural meteorology, minimun temperature factor is one of the important scientific basis for adaptable zoning of plant mechanism to increase yield and production of crop. Many tropical crops will be affected when the air temperature is less than 15^0C and strongly affected when the air temperature is less than 13^0C [1].

Actual agricultural production in Vietnam has shown a variety of plant such as coffee, rubber in the northern provinces, and a variety of cereals, fruit, other vegetables are killed by frost or by the very low temperature.

ENSO phenomena including El Nino and La Nina. In El Nino years, temperature is usually higher than the average annual temperature. In La Nina years, temperature is often lower than the average annual temperature, even lower from 2 to 3^0C. Thence, the damage cold and very cold temperature are often occur in La Nina years [2].

Assessment of the low temperatures effect on crop in the ENSO years is to zone adaptation areas for plant, to help managers and farmers selecting suitable plant and determining the optimal seasonal period to avoid the risk of damage caused by low temperature.

2. Methodology

2.1. Definition of safe period

Safe period is defined the period when minimum air temperatures (T_n) is less than

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critical temperature threshold of crop (T_c). Based on this result to decide the safe level or the safe zone for each plant. Table 1 shows the critical temperature threshold of some type of plants in the study area.

Table 1. The critical temperature threshold of some plant [1]

No	Crops	Temperature T_c (^{0}C)
1	Rice	13 - 15
2	Corn	10
3	Soy	10
4	Sunflower	8
5	Indian tea	0, -2
6	Coffee	5
7	Pepper	9
8	Rubber	15
9	Cinnamon, betel	-9, -10

2.2. Methods of safe period determination

Safe period for plant depends on the daily minimun air temperatures. It is necessary to define the starting and ending date of $T_n < T_c$ in dataset.

According to mathematical statistical method [3], the risk (R) of having one or more occurrences of temperature below the selected minimum temperature over a period of n years is calculated as:

$$R = 1 - C_n^k p^k (1-P)^n \quad (1)$$

where: C_n^k is combination of k = 0, 1 ,..., n and $P^0 = 1$.

For simplifying this expression gives the equation:

$$R = 1 - (1-P)^n \quad (2)$$

where: $P = P(T_n < T_c)$. Since this is the risk of having one or more damaging minimum temperature within n years, the certainty (C) of having no minimum temperature event is given by:

$$C = 1 - R = (1-P)^n \quad (3)$$

Therefore, the probability (P) of having minimum temperature event within any given year can be calculated from the certainty (C) as:

$$P = 1 - C^{\frac{1}{n}} \quad (4)$$

Where C is the fractional probability that the event will not occur within a specified number of years (n).

To determine the possible appearance of $T_n<T_c$, we use Gumbell distribution:

$$p(T_n < T_c) = 1 - \exp\left[-\exp\left(\frac{T_c - \beta}{\alpha}\right)\right] \quad (5)$$

Where: $\alpha = \sigma/1.283$, $\beta = \mu + 0.45\alpha$, μ is average minimum temperature and σ is the standard deviation of minimum temperature dataset. Based on Equation (5) and (3), we are able to determine the possible appearance of $T_n<T_c$ and (C).

Determination of starting and ending date of temperature $T_n<T_c$ is very important. This report has used the following probability distribution to define it:

$$p(T < T_c) = 100\left(1 - \exp\left[-\exp\left(\frac{d - \beta}{\alpha}\right)\right]\right) \quad (6)$$

Where, d is starting date of $T_n<T_c$,σd is standard deviation and μ is average deviation of starting date. Based on the above method, the starting and ending date $T_n < T_c$ can be defined with different probabilities.

2.3. Method of spatial data interpolation to determine safe zone

There are many methods for spatial data interpolation, each method has its own advantage depending on the type of data and geographical characteristics of the study area, so users should choose the suitable method. In northwest region, the terrain (elevation, slope, direction, stream valleys ...), meteorological and climatological conditions are complicated and variable in small scale. Further, this regional data is not much for studying (because of the hydro-meteorological, agricultural stations are sparse). To determine the safe zone, this report has inherited interpolation method [4], summary of this method is given by:

The length of safe period in a small subregion is strongly affected by factors such as: topography (elevation, slope, direction ...), geographical location (longtude, latitude) .. . The length of safe period can be calculated by:

$$f_t = f_{lt} + f_{rt} \quad (7)$$

where f_t is the number of safe day. f_{lt} is the number of safe day, which is calculated by the impact of the climate and terrain. f_{rt} is random error.

f_{lt} is calculated by the stepwise regression method with some factors: latitude, longitude, elevation.

When calculate f_{rt} component, we using the Distance Interpolation Method with Weights (IDWA).

$$f_{rt} = \sum_{i=1}^{k} \frac{1}{d_i^2} f_i / \sum_{i=1}^{d} \frac{1}{d_i^2} \quad (8)$$

Where f_0 is the value of interpolation point, f_i is the value of observation point i, d_i is the distance from point i to point 0, $k \geq 2$ is the interpolation radius range.

3. Data used

To define the possible appearance of $T_n<T_c$, this report has used daily minimum temperature data from 1961 to 2010 at the meteorological stations in the northwest region of Vietnam (Table 2). Data of ENSO phenonmena appearance (El Nino and La Nina) is described in Table 3.

Table 2. Location of meteorological stations in the Northwest of Vietnam

Station's Name	*Latitude (^{o}N)*	*Longitude (^{o}E)*	*Altitude (m)*
1. Sin Ho	22.21	103.15	1529
2. Moc Chau	20.51	104.38	958
3. Son La	21.50	103.34	676
4. Tuan Giao	21.35	103.25	570
5. Song Ma	21.04	103.44	302
6. Yen Chau	21.03	104.17	59

Table 3. The appearance of ENSO phenomena

El Nino year		*La Nina year*	
Starting month	*Ending month*	*Starting month*	*Ending month*
6/1963	2/1964	4/1964	1/1965
5/1965	2/1966	9/1967	4/1968
9/1968	2/1970	6/1970	12/1971
4/1972	3/1973	6/1973	3/1974
6/1976	2/1977	4/1975	3/1976
7/1979	12/1979	10/1984	12/1985
4/1982	9/1983	4/1988	3/1989
9/1986	1/1988	10/1998	3/2000
4/1991	6/1992	5/2007	3/2008
2/1993	8/1993		
4/1997	6/1998		
7/2002	1/2003		
9/2006	1/2007		
6/2009	4/2010		

4. Results and assessment

4.1. Results and assessment for safe period

Based on the method, meteorological data, minimum temperature threshold (T_c) and the time of ENSO phenomenon appearance, we had calculated the starting and ending time of safe period with probability of 80% following 3 scenarios: El Nino year, La Nina year and all year. Thence, the safe day is calculated for each specific region. The results are presented in Table 4 and Figure 1. From Table 4 and Figure 1 show that:

In all three scenarios, the safe day increases from high belt to low belt. At high belt, the beginning of $T_n<T_c$ is earlier and the ending of $T_n<T_c$ is later than low belt.

At most elevation, the safe day in El Nino year comparing with all year scenario, that increases from one to six days and the beginning of $T_n<T_c$ come later and the ending come earlier. Whereas, in La Nina year comparing with all year scenario, the safe day decreases from one to eight days and the beginning of $T_n<T_c$ come earlier and the ending come later.

For coffee tree, The critical temperature threhold is 5^0C, the safe day at different belts is different, the safe day at belt of 50-100m is 364 days, at belt of 1500-1600m is 314 days, the difference is 50 days. In El Nino year, the difference is about 44 days, in La Nina year is about 51 days.

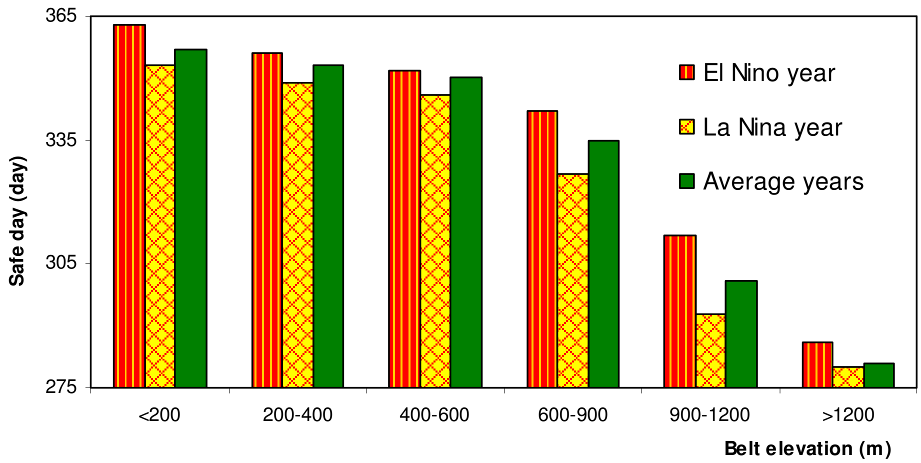

Figure 1. Safe days of plant with critical temperature threshold ($T_c \leq 5^oC$) in the Northwest region of Vietnam.

Table 4. The beginning and ending date of $T_n < T_c$ and the safe day according to the critical temperature threshold T_c in the Northwest of Vietnam

Belt elevation (m)	T_c (^0C)	Average years			El Nino years			La Nina years		
		Starting date	Ending date	Safe period (day)	Starting date	Ending date	Safe period (day)	Starting date	Ending date	Safe period (day)
<200	10	08/12	07/02	305	09/12	01/02	312	07/12	16/02	295
	8	20/12	18/01	337	20/12	10/01	346	18/12	17/01	337
	5	29/12	07/01	357	30/12	02/01	363	28/12	10/01	353
200-400	10	07/12	12/02	299	10/12	11/02	303	05/12	16/02	292
	8	19/12	25/01	329	20/12	19/01	336	17/12	27/01	325
	5	28/12	11/01	353	29/12	09/01	356	27/12	13/01	349
400-600	10	05/12	20/02	289	07/12	17/02	294	03/12	24/02	283
	8	18/12	28/01	326	19/12	25/01	329	17/12	01/02	320
	5	28/12	13/01	350	28/12	11/01	352	27/12	16/01	346
600-900	10	22/11	29/02	267	26/11	26/02	274	20/11	05/03	260
	8	08/12	04/02	308	08/12	01/02	312	08/12	09/02	303
	5	19/12	19/01	335	23/12	16/01	342	16/12	24/01	327
900-1200	10	14/11	19/03	240	16/11	14/03	248	12/11	20/03	237
	8	29/11	01/03	273	02/12	25/02	281	25/11	03/03	267
	5	10/12	13/02	301	15/12	07/02	312	05/12	16/02	293
>1200	10	30/10	22/03	222	01/11	18/03	228	27/10	25/03	215
	8	12/11	04/03	253	18/11	02/03	261	05/11	05/03	245
	5	27/11	20/02	281	28/11	17/02	286	27/11	21/02	280

4.2. Results for safe zone

Based on the safe period of each station according to ENSO scenarios, spatial interpolation equation of safe day (f_t) is defined for coffee (T_C = 5^0C) and rubber (T_C = 10^0C) in El Nino year and in La Nina year by using expression 7. The results about the spatial interpolation equations are presented in Table 5.

Table 5. The spatial interpolation equations

Tree	Scenario	Equation	Correlation coefficient (R^2)
Coffee	El Nino years	f_{lt} =-0.04651*h - 12.96861*φ+636.49368	0.8736
	La Nina years	f_{lt} = -0.05033*h - 9.4362*φ+552.95974	0.8728
Rubber	El Nino years	f_{lt} =-0.04958*h - 14.64764*φ+615.1782	0.8990
	La Nina years	f_{lt} =-0.05436*h - 11.49964*φ+539.54096	0.9157

Where: the symbols h and φ in the equation are altitude and latitude in each grid (pixel). The errors are handled by IDWA method (formula 8). By combining between f_{lt} and f_{rt} formula, safe zone is defined and thematic maps are established according to ENSO scenarios with grid resolution of 100x100 m (Figure 2).

Figure 2 shows the change on safety day in space for the northwest region of Viet Nam, that reflect the significant influence of topography. To help manager and farmer preventing damage of minimum temperature to coffee and rubber trees in the northwest mountain region, the area of safety day are presented in Table 6.

Table 6. The area of safety day according to ENSO scenarios in in the northwest mountain region of Vietnam

Safe period (day)	El Nino (in warm winter)		La Nina (in cold winter)	
	Safe zone (km^2)	Rate (%)	Safe zone (km^2)	Rate (%)
Coffee				
200- 250	304	0.93	284	0.81
250 - 290	3520	10.76	3540	10.88
290 - 330	19036	58.19	22453	68.64
330 - 365	9853	30.12	6436	19.67
Total	32713	100	32713	100
Rubber				
150 - 175	213	0.65	463	1.42
175 - 205	1238	3.78	1818	5.56
205 - 235	5708	17.45	7948	24.3
235 - 265	18625	56.93	18306	55.96
265 - 300	6929	21.18	4178	12.77
Total	32713	100	32713	100

From table 6, with coffee tree; in La Nina year, the safety day is often lower than in El Nino year, the safety day for coffee is from 200 to 365 days, the percentages of safety day at the hightest lavel (330 - 365 days) in El Nino and La Nina year are different (30.12% and 19.67%). With rubber tree, the safe day is ranging from 150 to 300 days. The percentages of safety day according to ENSO scenarios are also significant variable.

5. Conclusion

Based on the results of assessing the effect of minimum temperature on crop over the winter season in the northwest mountain region, it may provide some conclusions:

Method for calculating the beginning and ending date of $T_n<T_c$ is suitable for the study area. Based on the temperature T_c of each plant and information of the ENSO phenomenon can define the beginning and ending date of $T_n<T_c$ and safety day for each region.

Distribution of the beginning and ending date of $T_n<T_c$ with probability of 20% (for starting date) and probability of 80% (for ending date) is quite suitable with the distribution of elevation in the northwest mountain region. At the high altitude areas, the starting date is earlier and ending date is later than the lower regions. Similarly, safety day in high areas is usually shorter than in lower areas.

Damage caused by the effect of low temperature on rubber and coffee are particularly serious in recent years. Hence, the digital maps of the safety day for rubber and coffee trees are very useful; it provides a new method for disaster prevention in agricultural development of Vietnam in general and the northwest mountain region in particular.

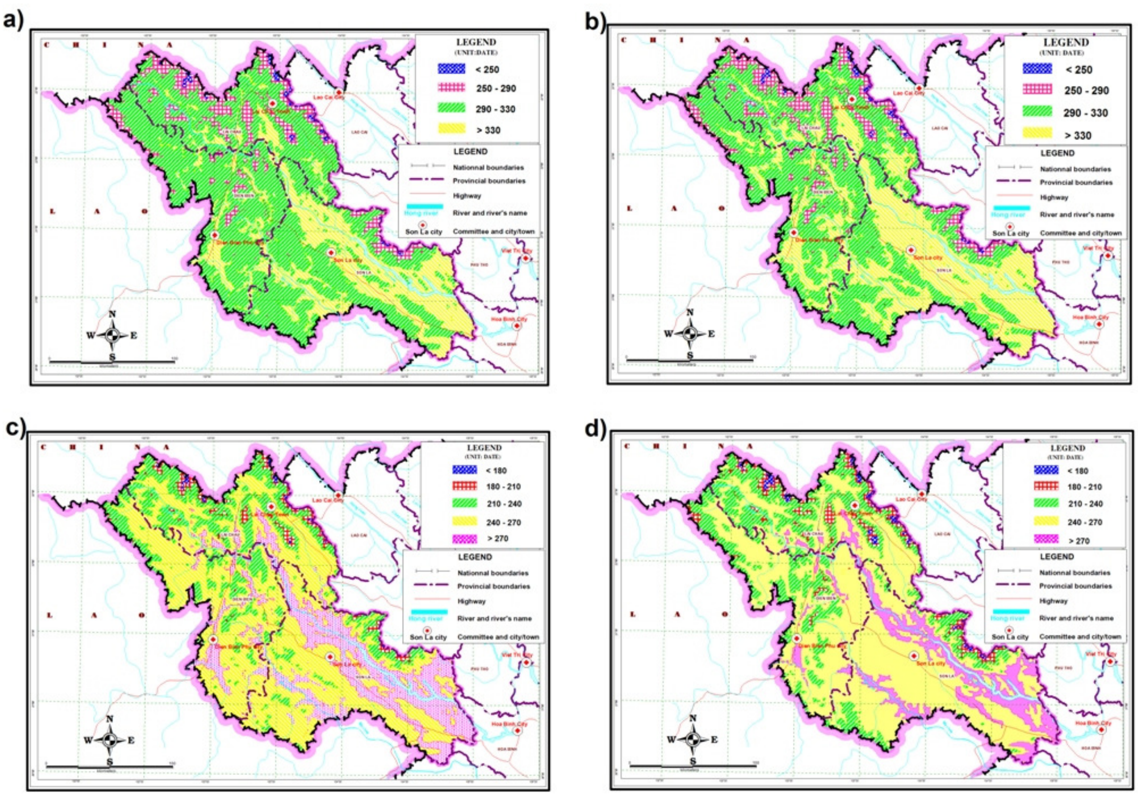

Figure 2. Digital map of safety days for the coffee ($T_c \leq 5^oC$) (figure a, b) and rubber ($T_c \leq 10^oC$) (c, d) Figure (a, c) in El Nino year, Figure (b, d) in La Nina year.

References

[1] Nguyen Van Viet. *Agricultural Meteorology Resources Vietnam*. Agricultural Publishers, Hanoi, 2009 (in Vietnamese).

[2] Mr Doc Minh. *The climate mountainous terrain*. Meteorological Publishers, Beijing, 1990, (in Chinese).

[3] Richard L Snyder, J. Paulo de-Abreu, Scott Matulich (2006). *Frost Protection Fundamentals Practice and economics*. Volume2-Food and Agriculture rganization of the United Nations Rome, Italia, 2006.

[4] Zhang Zhao. *Geographic information systems*. University Publishers, Beijing, 1995.