CHILLING UNIT IN RELATION TO THE DEVELOPMENT OF TEMPERATE FRUITS IN THE NORTHERN MOUNTAINOUS PROVINCE OF VIETNAM

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ABSTRACT

Aimed to properly determine the impact of weather condition in global climate changes circumstance specialized in annual chilling unit (CU) to the temperate fruit development in the Northern mountainous provinces, a study in the form of basically over all investigation was systematically conducted in which the method of overlapping the suitably related maps, the technologies of participatory rural appraisal (PRA), key informative persons (KIP) and geographical information system (GIS) were used as the principal tools. Results conducted from the study showed that the annual chilling unit calculated in two recent decades was unremarkably changed, closely related to the distribution of temperate fruit production in the studied region and it can be necessarily used for planning and projecting the development of these crops in the Northern mountainous provinces.

Keywords: *Investigation, temperate fruit, chilling unit, the Northern mountainous of Vietnam.*

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1. INTRODUCTION

Temperate fruit development in Vietnam is a step in the right direction, especially in Northern mountainous provinces that account for 30% of the total area but only contribute 9.6% of the total GDP. In addition to helping implement poverty alleviation and support the lives of people in these difficult areas, this development is to ensure food safety and reduce the amount of imported produce (especially from China). In this sense, temperate fruit production indirectly contributes to Vietnam's competitively advantaged fruit exports.

Temperate fruit in general and varieties of persimmons, pears, peaches, and plums in particular require a certain period of time in a year with chilling temperature suitable for floral initiation and development. Such fruit crops are mostly distributed in high-latitude countries of the world, mainly in Europe, America, and Northeast Asia. In fact, most temperate fruit cultivars need a high chilling requirement. For example, peach cultivars require about 600 - 1000 chilling units (CU), whereas plum cultivars require around 800 – 1200 CU [1]. Therefore, advances in fruit varieties and farming techniques are hard to be adapted to mountainous regions with subtropical climates in Southeast Asia, including Vietnam.

The sufficient accumulation of chilling required for floral bud initiation is in the genetics of the variety. In general, the majority of temperate fruit varieties require a temperature threshold for flower initiation between 0^0C and 15^0C, as a result of which, under temperature conditions below 0^0C or above 15^0C, flower bud formation cannot occur [2]. There is a growing demand for temperate fruit in Vietnam, particularly in big cities and places where the population is concentrated. High mountainous areas in the north and the central highlands with cold winters and receiving sufficient chilling are suitable for growing low-chill, temperate fruits. Varieties requiring medium-chill units can be grown in some locations. Ethnic

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minorities traditionally grow temperate fruits at an altitude of 800 - 2000 m above sea level [3]. Moc Chau district is largely situated on a plateau at an elevation between 800 and 1300 m above sea level, and with 200 - 600 chill units (CU), it is the most suitable district for temperate fruit production in Son La province. Lao Cai province has several districts, including Bac Ha, Sa Pa, Si Ma Cai, Bat Xat, and Muong Khuong, situated on high elevations above 1000 m having a cool climate with CU from 250 - 550 [4].

Using the Utah model or Dynamic and George - Nissen's simplified formula, which is later built into a specialized software, the number of chilling units (CU) of a region can be calculated, making the use of native or introduced varieties proactive and effective. This is also the reason why chilling unit have been studied over the last two decades in relation to the distribution and potential for temperate fruit development in the Northern mountainous regions of Vietnam.

2. RESEARCH METHODS

2.1. Studied objective

Chilling unit and current status of temperate fruit trees (pear, plum, peach, and persimmon) development in the northern mountainous provinces North Vietnam.

2.2. Methodology

Setting up questionnaires: Set up the questionnaires to gather information related to natural and social conditions in the provinces capable of temperate development (chilling unit – CU of 50 or more) in the Northern mountainous areas. These conditions include land, climate, weather, population, labor, traffic, etc. and the current condition of fruit tree production, especially temperate fruit tree production (area, variety, growth, fruit development)

Selecting locations for the survey: The overall investigation was conducted in Northern mountainous provinces to gain an overview of the current situation and calculate the possibility of developing temperate fruit trees throughout the region. Those regions with traditional development as well as sub-regions that have competitive advantages and are highly representative of each eco-sub-region should be a priority.

Carrying out the investigation: The application of participatory rural appraisal (PRA) methodology and key informative persons (KIP) method was used to gather primary data and information from relevant organizations (research institutes, universities, the Provincial Department of Agriculture and Rural Development, agriculture divisions etc.) along with undertaking fieldwork to assess the current condition of temperate fruit tree development in Northern Vietnam.

Calculating chilling unit (CU): By using the Prochill software, the average low temperature parameters of the coldest months of the year (mainly December, January and February depending on the year) were used to calculate the CU, referenced and compared with the Utah model (deduced from the temperature in 1 hour) and George – Nissen formula: ($Y = a+b/x^d$)

Processing survey results and planning development: Based on the climatic requirements of temperate fruit varieties, the GIS (geographical information system) method were utilized along with the use of specialized software like Mapinfo 10.5, ARCGIS 10 to overlap all kinds of adaptation maps (on land, climate, infrastructure, consumption market), in which adaptation maps on climate were the main focus.

2.3. Time and place of study

The study was carried out during the whole year of 2019 in some mountainous provinces in the North of Vietnam

3. RESULTS AND DISCUSSION

3.1. Chilling unit in recent years

Table 1. Synthesis of chilling unit accumulation (CU) in some areas (Using Prochill software, referred to George – Nissen formula: $Y = a+b/x^d$)

Location	2001	2002	2003	2004	2005	2006	2007	2008	2009	Average
Moc Chau district	167.1	303.1	350.8	253.0	280.6	220.9	340.2	316.3	395.0	*291.9 (5)*
Bac Yen district	82.2	198.8	221.0	142.1	196.0	134.8	212.5	207.0	253.0	183

Phu Yen district	-15.9	75.8	95.4	40.6	84.4	22.9	86.6	104.4	135.0	69.9
Co Noi district	48.6	185.3	180.1	106.7	144.6	123.0	165.0	169.7	253.0	152.9
Sin Ho district	309.7	650.7	463.7	430.5	406.6	398.9	503.4	410.5	588.8	*462.5 (2)*
Tam Duong district	134.8	250.0	214.5	148.8	265.1	185.3	229.5	185.3	296.6	*211.9 (7)*
Sa Pa town	485.5	662.1	741.4	628.3	633.9	601.4	974.0	650.7	915.0	*699.1 (1)*
Bac Ha district	259.0	336.8	379.9	309.7	383.7	309.7	410.5	446.9	508.1	*371.6 (3)*
Yen Bai province	28.7	99.9	120.6	118.2	142.1	56.8	140.0	188.0	177.4	119.1
Luc Yen district	21.0	99.9	113.6	99.9	137.2	73.6	152.0	185.3	191.0	119.3
Mu Cang Chai district	127.1	223.8	235.3	204.2	241.1	182.7	198.8	177.4	383.7	*219.3 (7)*
Nghia Lo town	22.7	99.9	120.6	80.1	120.6	67.3	130.0	159.5	180.1	109
Ham Yen district	28.6	82.2	109.0	95.4	132.4	54.8	125.3	174.8	190.7	110.4
Ha Giang province	44.6	86.6	111.3	99.9	147.0	67.3	157.0	174.8	198.8	120.8
Bac Quang district	26.8	93.2	111.3	95.4	120.6	58.9	139.7	174.8	177.4	110.9
Cao Bang province	113.6	172.3	111.3	142.1	259.0	95.4	244.3	340.2	256.0	192.7
Trung Khanh district	212.5	293.3	347.2	323.1	351.2	244.3	402.7	575.5	395.3	*349.5 (4)*
Bac Kan province	61.0	113.6	157.0	137.2	172.3	84.4	170.0	232.4	215.3	149.2
Ngan Son district	182.7	259.0	253.0	280.6	233.3	190.7	350.8	451.1	402.7	*289.3 (5)*
Bao Lac district	154.7	118.2	149.5	104.4	159.5	75.8	193.3	209.7	212.5	152.9
Dinh Hoa district	36.6	97.7	147.0	120.6	152.0	56.9	147.0	207.0	196.4	129
Lang Son province	152.0	209.2	241.1	226.6	303.1	165.0	271.2	442.7	313.0	*258.2 (6)*
That Khe town	123.0	164.6	221.0	188.0	274.3	128.0	247.8	383.7	265.1	*221,7 (7)*
Son Dong district	146.6	99.9	95.4	84.4	137.2	73.6	113.6	209.7	177.4	126,4
Luc Ngan district	34.6	93.2	139.7	113.3	149.5	58.9	125.3	232.4	177.4	124.9

Tien Yen district	73.6	123.0	169.7	127.7	169.7	84.4	149.5	215.3	182.7	144
Da Lat city	77.9	102.2	95.4	-55.0	109.0	67.2	75.8	77.9	147.0	77.5
Bao Loc district	-60.0	-59.9	-59.9	-38.4	-48.5	-72.6	-58.3	-80.4	-58.3	-59.6

In the context of accelerating climate change with global temperature increasing over time, the first issue that needs addressing is to consider whether traditional highlands in Vietnam in general and the northern mountainous areas in particular can meet mandatory demand for sufficient chilling. If the demand can no longer be met, what solutions are needed to maintain the available temperate orchards.

Meteorological data were collected in these regions, especially the minimum average temperature in each area. Some of the regions are representatives of the Northern mountainous areas, where temperate fruit cultivation is exploited such as Moc Chau district (Son La province), Dong Van district (Ha Giang province), Trang Dinh district (Lang Son province), Bac Ha district, Sa Pa town (Lao Cai province).

After the calculation using Prochill software along with references to the Utah model and formula proposed by George *et al.* (1998b) [5], the data is presented in graphs and divided into two stages: from 2001 to 2009 (Table 1 and figure 1a, 1b) and the most recent 5 years from 2015 to 2019 (Figure 2).

Comments:

* From 2001 to 2009: The CU value for 10 years in each location changed over time but generally there was no major fluctuation except for Sa Pa town in 2002 and Sin Ho district in 2007, 2008, and 2009. This means that in general, the accumulation of chilling is relatively stable in the context of climate change.

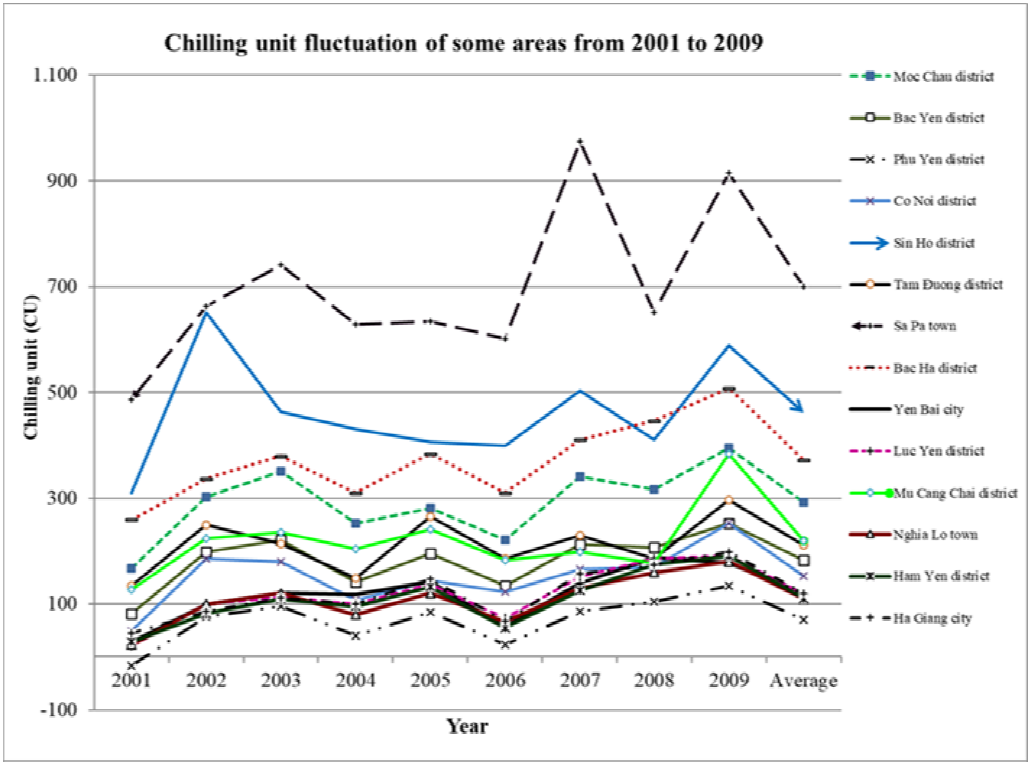

Figure 1a. Chilling unit fluctuation of some areas from 2001 to 2009

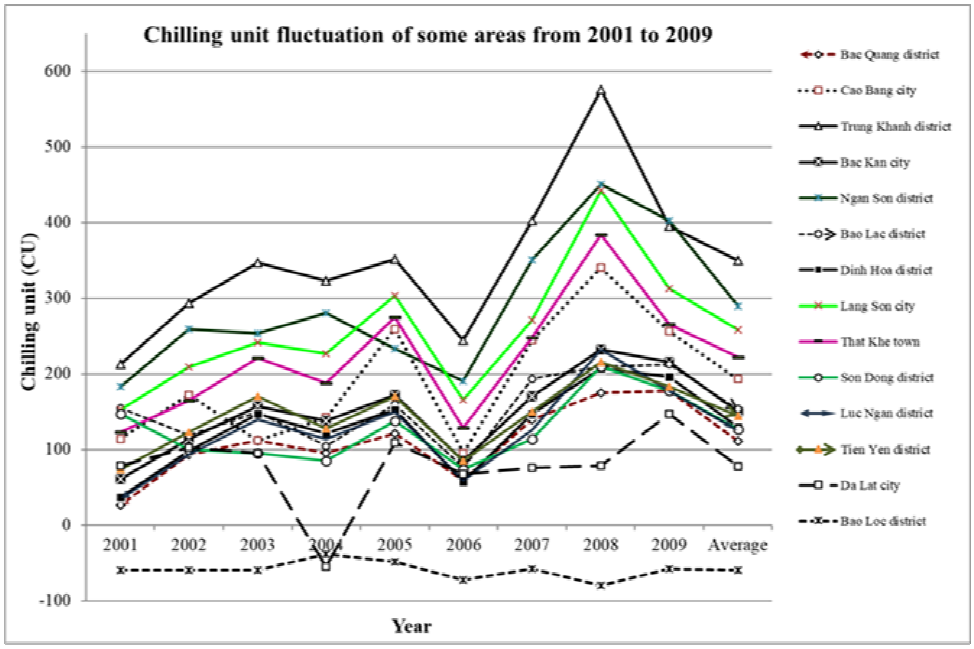

Figure 1b. Chilling unit fluctuation of some areas from 2001 to 2009

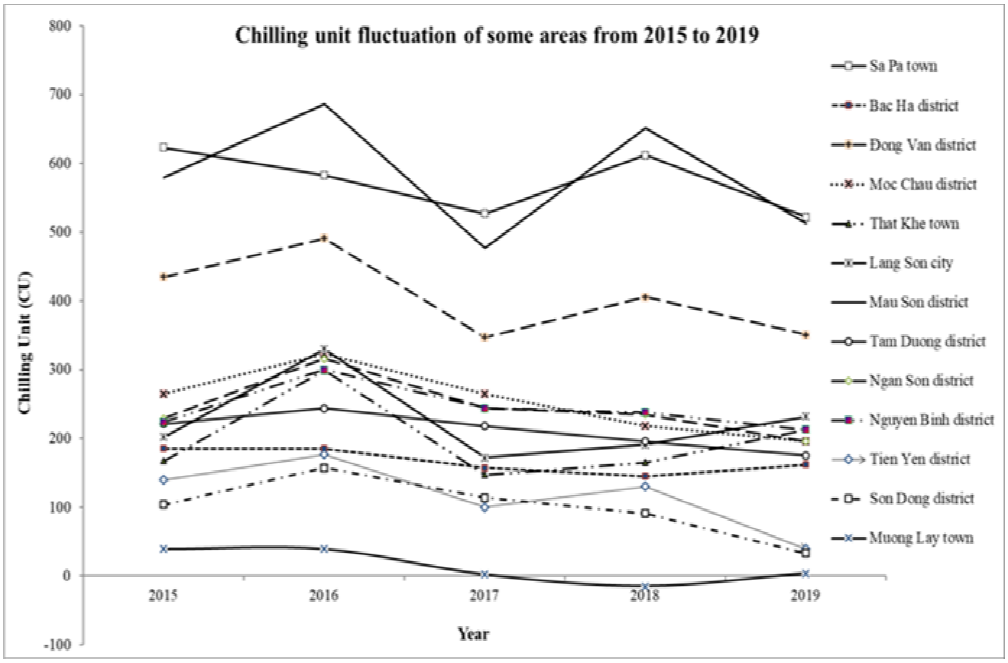

Figure 2. Chilling unit fluctuation of some areas from 2015 to 2019

Based on the average number of chilling hours in 10 years (ranked in parentheses attached to the following) and compared to the chilling requirement of temperate fruit varieties in general, the studied areas can be divided into 3 groups:

- Group 1: Includes Sa Pa town and Sin Ho district with chilling hours between 450 and 650 CU, especially with a few years exceeding 700 CU. This value range allows floral initiation for temperate fruit varieties with high chilling requirement (high chill cultivars).

- Group 2: Includes Bac Ha district, Trung Khanh district, Moc Chau district, Ngan Son district, Tam Duong district and That Khe town with the average number of chilling hours ranging from over 200 CU to below 400 CU, mainly between 200 and

300 CU. This chilling range allows cultivation of moderate chill cultivars and low chill cultivars.

- Group 3: Include the remaining areas with chilling hours around 100 CU, even with negative values (such as Bao Loc district, Lam Dong province). Temperate fruit production and development is not recommended in these areas. Only places with chilling hours of approximately 100 CU (such as Son Dong district and Tien Yen district) can be considered, provided that these areas are given varieties with low chilling requirement and supported with technical measures (leaf cutting, branch downwards; growth regulator application.

* From 2015 to 2019: With the aim of making a feasible plan for developing temperate fruit, the research focused only on regions with more advantages in chilling accumulation. Dong Van district, which represents 4 upland districts of Ha Giang province, is added as a sample to the study. This area has high potential due to suitable climatic conditions for growing temperate fruit trees and in practice, its contribution to the local economy is significant (Table 1).

The fluctuation of the chilling unit tends to be similar to that in phase 1. Overall, the annual number of chilling hours fluctuates slightly, but the fluctuation is not significant. These studied regions basically ensure the flower initiation of moderate and low chill cultivars, in which the low chill varieties need to be paid more attention.

3.2. Development of temperate fruit trees in some Northern mountainous provinces in recent years

Aimed to understand the development of temperate fruit trees in relation to climatic conditions, several locations that had sufficient chilling accumulation for flower initiation of some temperate fruit varieties were selected for sampling. The figures were summarized in table 1, 2 and 3.

Table 2. Area and production of temperate fruit trees in Ha Giang province

No	Species	2016		2017		2018		2019	
		Area (ha)	Total yield (tons)	Area (ha)	Total yield (tons)	Area (ha)	Total yield (tons)	Area (ha)	Total yield (tons)
1	Pear	724.0	2,103.8	946.5	2,300.5	980.5	2,517.9	1,282.7	4,966.6
2	Plum, peach	1,148.9	1,973.8	1,147.9	1,839.4	1,183.8	2,044.0	1,920.1	4,561.5
3	Persimmon					445.9	523.2		

In all 3 locations, the area and total output tended to increase significantly in recent years, especially in Ha Giang province (Table 1) and districts such as Moc Chau district (Table 2) and Bac Ha district (Table 3), in which production of pear trees in all 3 locations, plum trees and peach trees in Ha Giang province has increased quite considerably in the last 3 or 4 years.

On the whole, the increase in area that entails an increase in the production of temperate fruit trees was due to various subjective and objective causes. The temperature factor, namely the chilling unit accumulation, was not a sufficient condition yet it was a necessary and mandatory factor. The data presented in the tables of this article is only intended to add a testament to the fact that climate change has not had a considerable impact on chilling accumulation. Some varieties of temperate fruit trees can still flower and bear fruit despite rising global temperature.

It should also be added that the chilling unit (CU) value is not equivalent to coldness. The chilling unit is determined at a certain period of time in the rotation of a year when temperate plants in general and temperate fruit trees in particular move from vegetative staging to reproductive staging, precisely the preinitiation stage.

Table 3. Area and production of temperate fruit trees in Moc Chau district

No	Species	2016		2017		2018	
		Area (ha)	Total yield (tons)	Area (ha)	Total yield (tons)	Area (ha)	Total yield (tons)
1	Plum	1,413.0	13,273.0	1,439.0	11,299.0	1,951.0	16,700.0
2	Persimmon	19.0	465.0	41.0	442.0	45.0	464.0
3	Peach	42.0	175.0	48.0	184.0	58.0	197.0
4	Pear	133.0	822.0	115.0	693.0	105.0	499.0
	Sum	1,607.0	14,735.0	1,643.0	12,618.0	2,159.0	17,860.0

Table 4. Area of some temperate fruit trees in Bac Ha district, Lao Cai province

Year	Area of land (ha)	Area of temperate fruit trees (ha)	% in area of land	Temperate fruit species				
				Peach	Persimmon	Pear	Plum	Others
2010	-	685	-	60	23	95	477	30
2011	-	840	-	80	23	135	572	30
2012	-	916	-	93	23	185	585	30
2013	-	983	-	98	23	247	585	30
2014	-	1,008	-	98	23	272	585	30
2015	-	1,035	-	98	23	286	593	35
2016	-	1,042	-	98	23	286	600	35
2017	-	1,092	-	105	23	286	643	35
2018	-	1,167	-	115	23	300	693	36
2019	4,6126	1,207	67,5	120	23	315	712	37

3.3. Chilling unit in relation to the issue of distribution and planning of temperate fruit cultivation

The map of the distribution of temperate fruit trees in the Northern mountainous region, as shown in Figure 1 is made using the results of the survey conducted in 2019 and 2020, referencing documents from local management agencies.

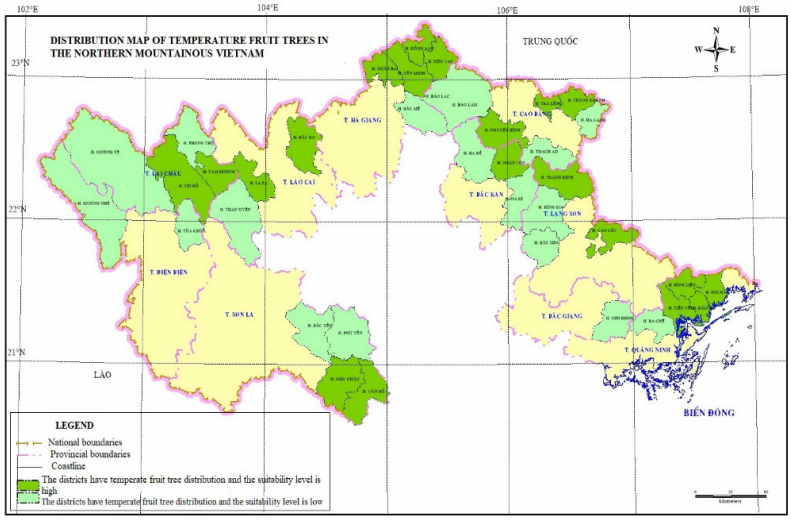

Figure 3. Map of the distribution of temperate fruit trees in the Northern mountainous region

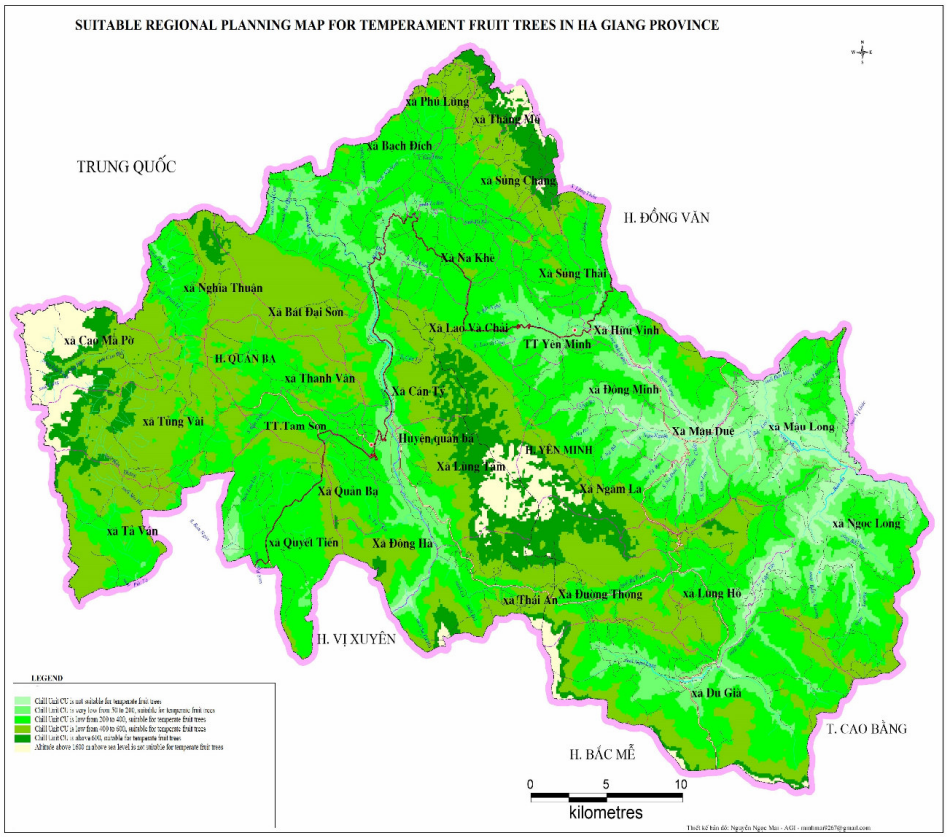

Figure 4. Map of temperate fruit tree planning in Ha Giang province

Planning maps are created for each region based on the average value of chilling unit (CU) over many years along with other climatic factors such as air humidity, monthly precipitation, radiation, while taking extreme factors into consideration like hoarfrost and hail. It also refers to and integrates information using GIS tools taken from land plots (soil type, thickness, steepness, components), using the overlapping maps method. Therefore, these maps are heavily inclined to the potential meaning of it. One of the main factors is the chilling unit value. An example is Ha Giang province (Figure 2) and 4 of its upland districts bordering China: Quan Ba district, Yen Minh district, Meo Vac district, and Dong Van district with high chilling accumulation (above 500 CU), which shows great potential for temperate fruit development.

Thus, it can be indicated that the chilling unit is closely related to the current distribution/development and planning of planting areas for temperate fruit trees. Due to the limitations within the framework of an article, this will be analyzed further on another occasion.

4. CONCLUSION

The chilling unit value in most Northern mountainous provinces maintains a constant relative stability despite abnormal changes in the weather conditions.

In regions with potential climatic conditions, temperate fruit trees tend to grow quite strongly in recent years.

Chilling unit value is closely linked to the current state of distribution and is one of the basic factors in elaborating the planning on temperate fruit development in the Northern mountainous areas.

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