The effect of rainfall on cardamom production in bhutan

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ABSTRACT

Large cardamom is one of the largest value potential perennial cash crop of Bhutan just second to the cordyceps. It usually grows up to the height of 2.5 meter especially between 700-1800m asl. It requires good amount of shade and grows well especially in the southern region of Bhutan. Although there are many factors that would account for the production of cardamom such as orientation of the site, density of shade, elevation of the site, climate and temperature etc. Water also plays a vital role in the overall quality and the yield of the cardamom, but if there is excess of water it deteriorates its yield and overall production. Having excess water in the soil mass tends to rot the roots and the lower steam of the plant and eventually making it vulnerable to fungus pest and diseases, thus lowering the yield. Therefore, an optimum amount of water is required for maximum production of cardamom. The yield is proportional to the water content up to certain limit, then the yield decreases with the increase of water content. This investigation also shows the gradient of the cultivated land contributes in the production of Cardamom.

Keywords: *Amomum subultum, PET, Gradient, Runoff, Precipitation, Yield, Disease*

Introduction

The type of cardamom species found in the Himalayan region is called as *large cardamom*, greater cardamom, brown cardamom or Nepal cardamom. This particular type of cardamom comes from the species Amomum subultum and is native to the eastern Himalayas and are mostly grown in Nepal, Sikkim and India (Chains, 2017). Its locally called as *barlang* in Bhutan, *Bada elachi* in Hindi and *alaichi* in Nepali.

The Lepchas were considered as first to harvest large cardamom capsules. They harvested from the natural forests mostly and used in medicinal purposes and as an aromatic edible with fruit.(Ajmera et al., 2018)

Large cardamom (*Amomum subultum*) was first introduced to Bhutan in the early seventies and has since become an economically valuable perennial cash crop in southern region, with total acreage reaching 6968 ha in 1994(Department of Agriculture, 2010). The total yielding of cardamom cultivation under the area of 4293.73 ha was approximately 2091 MT.(Department of Agriculture, 2010)

The Bhutanese themselves are not the major consumer, majority of the production is exported in Bangladesh and India. More than 845MT of cardamom worth approximately Nu. 940.85M was exported in India and Bangladesh (Department of Agriculture, 2010), and only small number is consumed locally. Currently Cardamom is grown in all the Dzongkhags except Thimphu, Bumthang and Paro. The leading Cardamom growing dzongkhags are Samtse, Sarpang, Chhukha, Dagana and Zhemgang. Bhutan's large Cardamom industry emerge big mostly because of the lucrative pricing, which encouraged the farmers to grow cardamom in large scale irrespective of shade and overall

management requirement for the healthy production of the spice. This kind of practice has reduced the production and increased in the disease, insects and other production related problems. The growth in production of Cardamom has increased over the past few years and then the declination happened. In Bhutan, two key diseases- Fusarium oxysporum wilt and colletotrichum blight- have been causing severe damage to cardamom plantations (Rijal & Rabgyal, 2019). Their effect is exasperated by Chirkey and Furkey, the other viral diseases prevalent in the crop(Belbase et al., 2018). Other reasons for decline in large cardamom include the follow of old planting pattern and unhealthy practice management, lack and inaccessible of quality planting material, and scarcity of irrigation facilities, lack of training and also lack of financial support(Washingotn & Washington, 2019).Fairly well distributed annual rainfall (1500- 4000mm) & cardamom thrives well in areas having warm humid climate. An altitude of 600-1200 m above MSL is ideal & a temperature range of 18 - 28 C. Flowering and shade for proper growth (Ajmera et al., 2018). Adopting appropriate scientific methods like nursery establishment, seedling preparations, soil management along with introduction of disease resistant and high yielding varieties and advance technologies can promote and increase the cardamom industry and support the farmers. A new perspectives is required for water storage to manage the effects of increased in the evapotranspiration, rainfall, inter-seasonal variation, etc. the due to Climate change in all the ecosystems. (Watson, 2008).Large cardamom is a continual which require good amount of shade and is found at between 600–2,400 masl. It also requires a large amount of humidity and, therefore, grows well in site where the yearly rainfall ranges from 2,000–4,000 mm and the atmospheric air temperature ranges from 10–22ºC (Sharma et al., 2016). The antimicrobial properties is reported to be found in oil of large cardamom and is widely used in ayurvedic medicine preparations. A more recent use of large cardamom is the high value pan masala which is because of increased use of large cardamom. *Amomum subulatum* is a perennial cash crop which is usually grown along with trees to provide shade. It is mostly grown under Himalayan alder (*Alnus nepalensis*) or sometimes the mixture of various tree species. (Bisht et al., 2010) because of the increase in the production in the use of large cardamom. It is a perennial cash crop grown under Himalayan mixed forest tree species. The other name of the plant includes black Cardamom of greater Indian Cardamom and is considered evergreen or semi-evergreen.(KC, 2019).

Methodology

The survey was designed as a descriptive pilot study interview and using questionaries to the cultivars. The interview was done to get the annual production and income for five years and also, the current challenges faced and measures used in overcoming the problems associated with. Field visit was done to see the location and orientation of the cultivated land. The questionnaire was also designed for the local government for the properties of the soil and support provided for enhancing yield. The pH, soil indices, permeability etc., was not determined and also the limited equipment was the problem. The annual Rainfall for past five years were obtained for Bhutan RNR, Statistics.

Study area

Tsebar which lies at the elevation of 170 MSL coordinate (26.87, 90.9) under Khar Gewog which is located about 100 km from Pemagatshel main town was selected as the study site as shown in Figure 1. Two different cultivated sites were selected for the study base on the gradient on the land that is gentle slope and fairly plane slope.

The first selected site which has a gentle slope of elevation 1374.3 MSL which lies at the coordinate (27.01,90.9) and the other which has a fairly plane slope of elevation of 1379 MSL which lies at the coordinate (26.98,91.36).

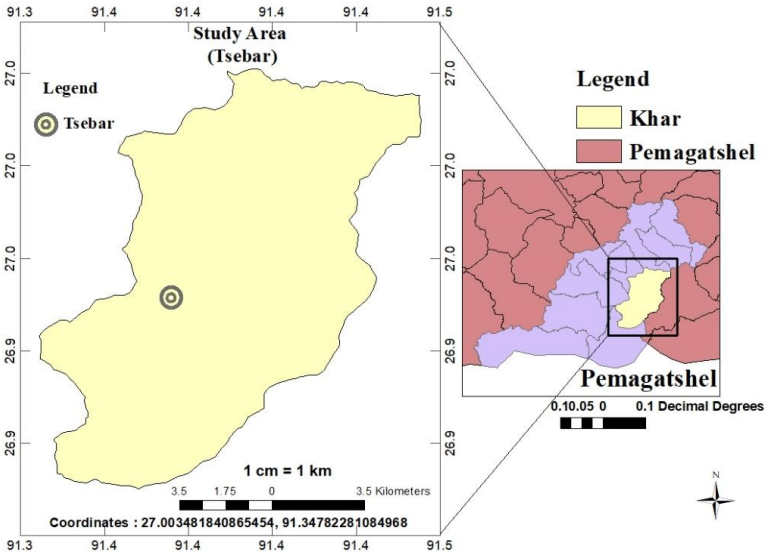


Figure 1: Study Area.

Major findings and discussion

Primary Data

Table.1 shows the annual yield products (dried capsules) of fives cultivars for 5 years. The two selected sites which were own by Kezang Phuntsho

and Penjor has a land gradient of gentle slope and plane respectively. There is not much of variation although there is an increase of yield for first three years and then the yield decreases for the following years by 22%

Table 1: Annual cardamom yield

Sl.no	Cultivar	Area(acre)	Elevation(MSL)	Coordinate	Year	Annual product (Nu)	Yield(kg/acre)
1	**Kezang Phuntsho**	1.8	1374.3	27.01,90.9	2014	250.0	138.889
					2015	256.0	142.222
					2016	266.0	147.778
					2017	261.0	145.000
					2018	264.6	147.000
2	**Penjor**	1.1	1379	26.98,91.38	2014	156.0	141.818
					2015	160.0	145.455
					2016	175.0	159.091
					2017	170.0	154.545
					2018	167.0	151.818
3	**JungKhar**	0.7	1373.4	26.84,91.14	2014	110.5	158.000
					2015	125.0	179.000
					2016	129.0	184.000
					2017	100.0	143.000
					2018	93.0	133.000
4	**Jigme Tshering**	0.5	1367.7	26.92,90.86	2014	90.0	180.000
					2015	112.0	224.000
					2016	116.0	232.000
					2017	86.0	172.000
					2018	88.2	176.000
5	**Ngajay**	1.0	1369.6	26.5,91.77	2014	90.0	90.000
					2015	120.0	120.000
					2016	194.5	194.500
					2017	190.0	190.000
					2018	152.0	152.000

Secondary Data

The annual cardamom yield and mean annual rainfall for 4 years of different dzongkhags is presented in Table 2. The linear relation between annual yield and mean annual is determined. Table 3 contain the relative humidity and Table 4 contain the temperature recorded of past few years of Pemagatshel. Figure 2,3,4 and 5 shows annual cardamom yield for various dzongkhags in 2014 to 2017.

Table 1: Mean annual rainfall and annual yield.

Source : (*Bhutan RNR, Statistics*, 2018)

Table 2:Mean relative humidity

Stations	2014		2015		2016		2017	
Dzongkhags	**Mean**	**Yield (Kg/Acre)**	**Mean**	**Yield (Kg/Acre)**	**Mean**	**Yield (Kg/Acre)**	**Mean**	**Yield (Kg/Acre)**
Bhur	325.850	130.000	438.367	167.000	447.842	200.000	494.192	121.000
Chamkhar	56.450		58.792	0.000	61.675	0.000	69.817	0.000
Dagana	102.325	164.000	116.258	150.000	108.733	333.000	95.625	135.000
Damphu	126.208	125.000	137.683	67.000	157.892	188.000	116.317	90.000
Doethang	281.217	140.000	319.992	134.000	303.317	270.000	298.475	67.000
Gasa	171.992		215.850	0.000	161.667	0.000	202.367	0.000
Haa	70.367	153.000	86.908	177.000	81.400	294.000	71.533	39.000
Kanglung	78.733	178.000	88.533	140.000	86.967	221.000	92.967	26.000
Mongar	75.633	80.000	72.892	29.000	82.267	160.000	85.400	21.000
Paro	46.817		53.867	0.000	57.958	0.000	32.233	0.000
Pemagatshel	119.817	207.000	141.025	5.000	138.250	10.000	137.467	21.000
Punakha	58.000		69.708	0.000	268.875	203.000	414.950	59.000
Sipsu	342.642	250.000	465.458	242.000	52.017	247.000	65.533	224.000
Semtokha	56.025		46.917	0.000	428.150	0.000	497.367	0.000
Tangmachu	56.308	73.000	64.625	0.000	59.325	204.000	50.558	7.000
Trashiyangtse	79.933		105.158	0.000	59.425	0.000	78.625	1.000
Trongsa	103.908	72.000	121.492	63.000	103.875	167.000	103.342	51.000
Wangduephodrang	42.767		64.550	0.000	114.000	0.000	130.600	6.000
Zhemgang	117.575	168.000	129.617	66.000	52.217	98.000	47.467	52.000
Phuntsholing	294.000	170.000	350.083	193.000	130.583	266.000	113.233	66.000

Relative Humidity (%)												
Year	January	February	March	April	May	June	July	August	September	October	November	December
2014	15.6	15.9	18.1	21.9	22.3	23.7	24.8	23.9	24.3	23.1	19.6	17.4
2015	16.5	17.9	22.7	20.6	23.3	23.2	24.1	24	24.3	23.5	20.2	15.8
2016	14.5	17.7	21.2	23	23.2	25.2	22.9	25.5	24.3	24.8	21.4	18.7
2017	17.3	18.6	18.4	21.9	24.1	25.1	24.9	24.6	24.7	24.2	21.2	19.4

Source : (Royal Government of Bhutan Climate Data Book of Bhutan, 2018)

Table 3: Monthly recorded temperature

Monthly recorded Temperature (^{o}C)									
	2014			2015			2016		
Month	max	min	avg	max	min	avg	max	min	avg
January	15.60	4.00	9.80	16.50	5.60	11.05	14.50	5.30	9.90
February	15.90	4.40	10.15	17.90	6.90	12.40	17.70	8.00	12.85
March	18.10	7.90	13.00	22.70	10.90	16.80	21.20	11.10	16.15
April	21.90	11.20	16.55	20.60	12.70	16.65	23.00	14.00	18.5
May	22.30	14.90	18.60	23.30	16.20	19.75	23.20	15.30	19.25
June	23.70	17.20	20.45	23.20	18.30	20.75	25.20	18.00	21.60
July	24.80	18.10	21.45	24.10	18.50	21.30	22.90	18.50	20.70
August	23.90	17.70	20.80	24.00	18.70	21.35	25.50	18.60	22.05
September	24.30	16.40	20.35	24.30	18.00	21.15	24.30	18.20	21.25
October	23.10	13.20	18.15	23.50	13.50	18.50	24.80	14.00	19.40
November	19.60	8.00	13.80	20.20	9.90	15.05	21.40	10.00	15.70
December	17.40	6.10	11.75	15.80	5.50	10.65	18.70	7.50	13.10

Source: (*Royal Government of Bhutan Climate Data Book of Bhutan*, 2018)

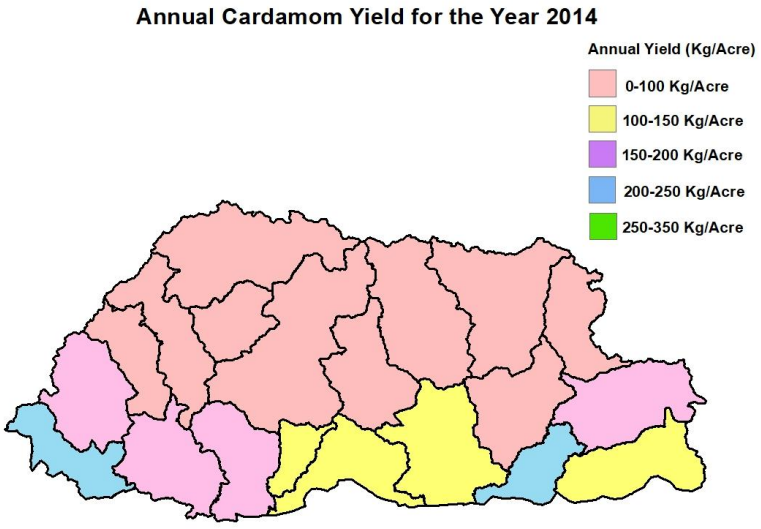


Figure 2. Annual yield, 2014

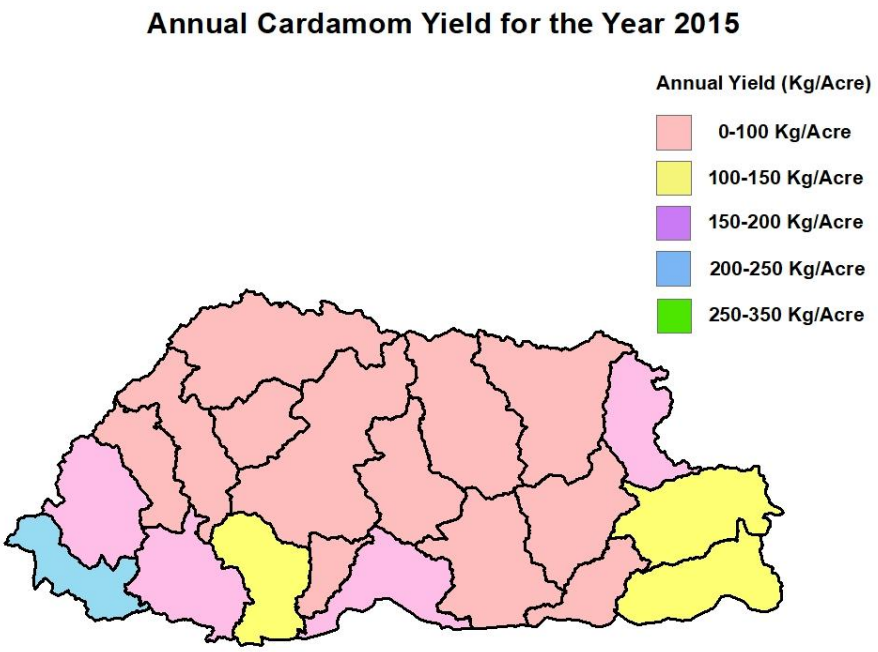


Figure 3. Annual yield, 2015

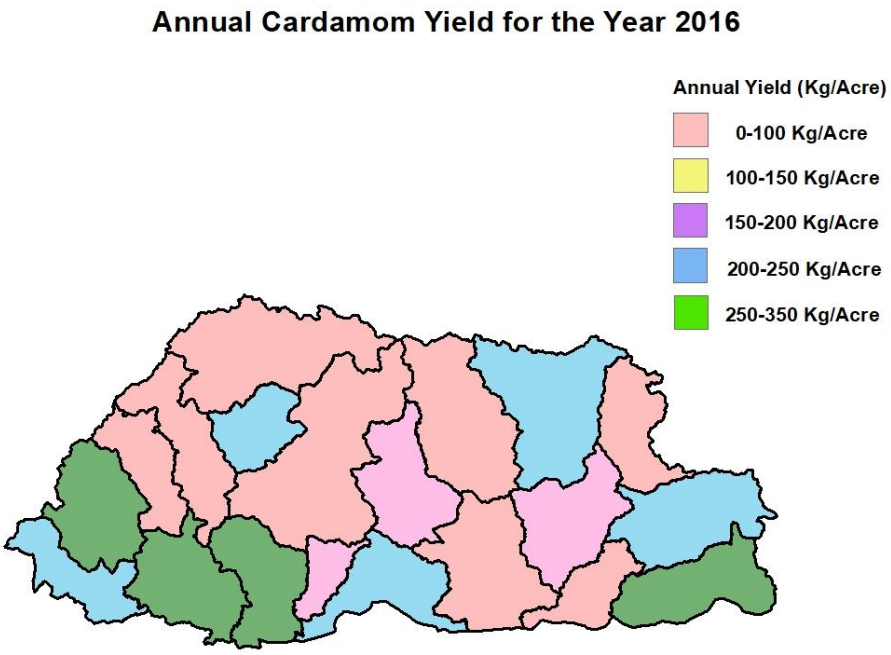


Figure 4. Annua yield, 2016

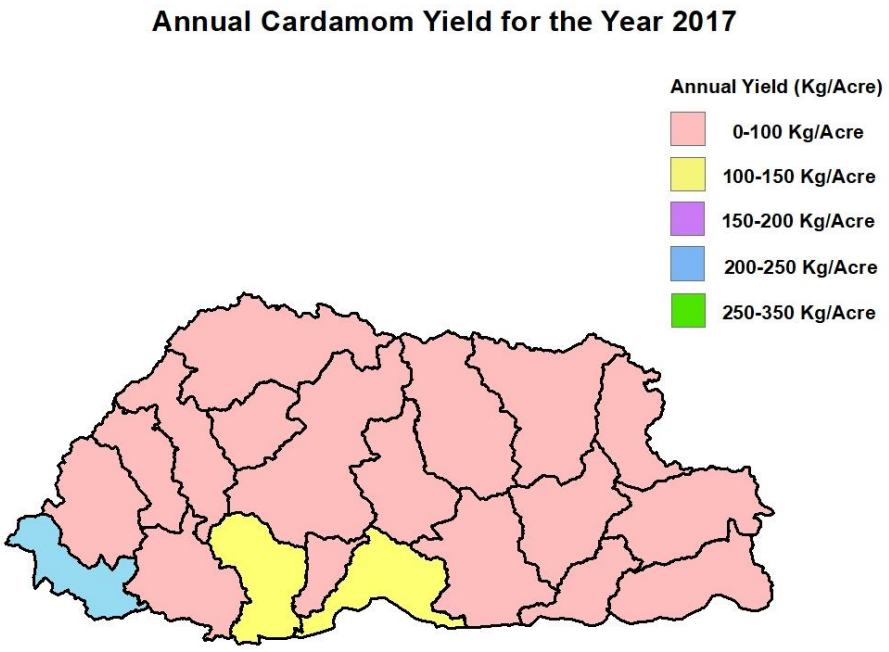


Figure 5. Annual yield, 2017

Status of cardamom

Field visit and interview with the farmers shows that there are many diseases and pests prevailing in the cardamom bushes among which some are known and some are still unknown. Majority of the farmers from Pemagatshel area don't know much of the diseases.

Case A: Burning leaf

Leaf burning is found is every field and majority of this problem is found where there is lack of shade in the cultivated land and is found more in the fairly plain slope.

Figure 6. Burning leaf

Case B: Stem hardening disease

The stem becomes stiff and hard with scars in leaves as the pseudo-stem at base thickens. This disease is found as clustered. Such disease is prominent. This disease can transfer from one plant to the nearby plant.

Figure 7.Stem hardening

Case C: Blight Disease (Dry leaves disease)

The whole cardamom plant is dried and this is solely found is more exposed area. Other diseases like Chirkey Disease and Leaf infection were not found during field survey although such diseases found to be prevailing by previous researches.

Figure 8. Blight

Case D: **Stem Borer**

The diseased plant is found to have Larvae with the stem. However, other various pests are unknown. Leaves are found with stromata.

Water Management

There are no irrigation facilities for all the region in the study site and slope of the land is gentle to steep. They simply depend on rainfall.

Harvest process

The product is collected using hooked iron rod and capsules are simply plucked out in eastern region. The capsules are then sun dried in open atmosphere.

Use of any technological approach

No sophisticated machine or any sort of technology is implemented. Every work is based on labor.

Marketing Channel

There is no official market linkage as such. Cultivars are engaged in production of large cardamom, followed with the harvest, curing and storing, and then marketing. All the processes mentioned above is based on labor work. The capsule is directly sold to local traders. Or sometimes it is sold to third-party who have marketing linkage to border town. Figure 9 shows the marketing channel of the study site.

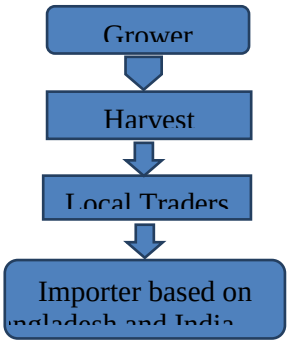


Figure 9. Marketing channel

Government management and nurseries

The *Barling* seedling was provided by local government that was free from disease. The electric fence was introduced all round that community to defend their field from animal threat. The nurseries or Centre is unavailable in locality.

Soil Quality

No test was conducted to find the pH, Permeability, Soil Indices of the soil. Overall, the quality of soil has degraded as per the land holders. The texture ranges from shallow sandy loam to clayey loam and is mixed red and black soil.

Results

Data Analysis

The calculation of missing data was done by normal ratio method:

$$p_x = \frac{1}{M}\left[\frac{p_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right]$$

Where,

p_x = Missing annual precipitation at station X not included in the above M stations.

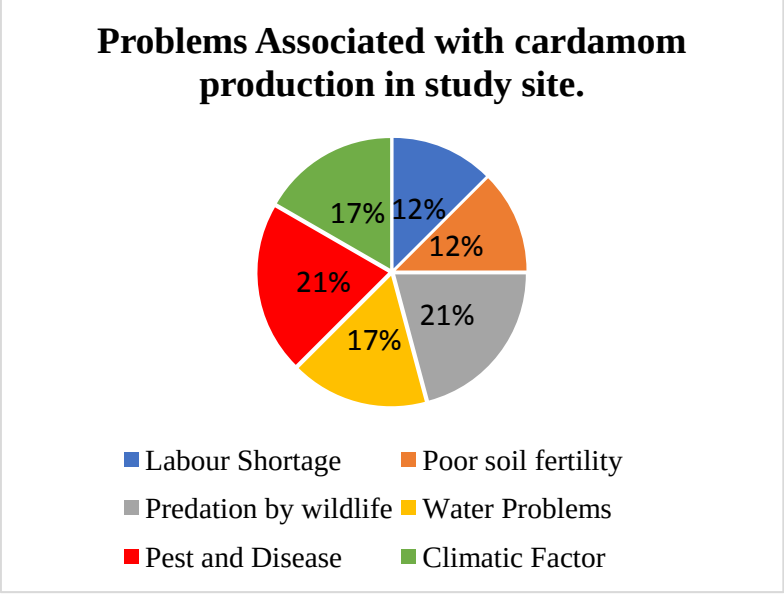
$p_1, p_2,$ = Annual normal precipitation for station x

N_1, N_2 = Annual precipitation of the other station above M.

M = Total number of stations – 1

This method was used in estimating the total rainfall in Phuntsholing station for 2014 and 2015.

Figure 10. Shows the percentage wise factor affecting Cardamom yield for the selected



The Statistics analysis of rainfall was done in MS Excel. The correlation between mean yearly precipitation and the annual yield was determined for the past four years of Bhutan, 2014, 2015, 2016 and 2017 and also the correlation between mean yearly precipitation and the annual yield of the two study sites were determined for the comparison.
The equation of the straight-line regression between the annual yield and the annual mean precipitation is also computed and it is given by the equation:

$$Y = a * M + b$$

Where,
Y = Annual yield
M = Annual mean rainfall
a and b are the coefficients

The value of a and b is calculated as:

$$a = \frac{N\sum YM - \sum Y \sum M}{N\sum M^2 - (\sum M)^2}$$

$$b = \frac{\sum Y - a * \sum M}{N}$$

Where, N is the number of observations.
Figure 11 shows the relation between mean yearly rainfall and yield for four years. Figure 12 and figure 13 shows the relation between mean yearly precipitation and yield of four years of the two study sites. Figure 14 present the mean yield and mean annual rainfall linear relation of four years. Table 5 shows the correlation of yield with respect to mean annual rainfall for some leading Cardamom producing Dzongkhags.

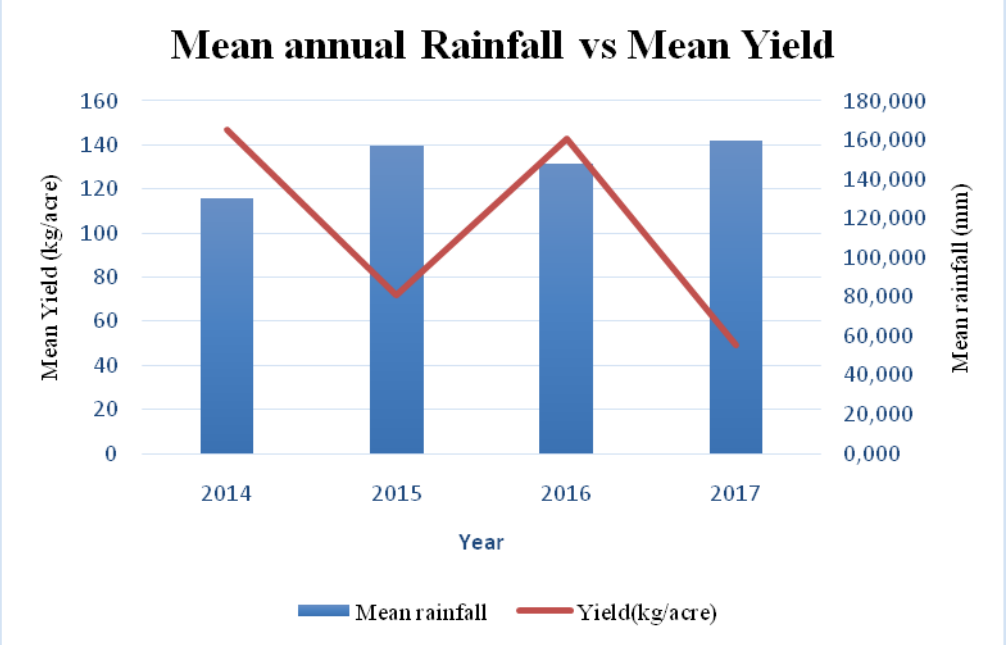


Figure 10: Yield vs Rainfall for gentle slope site

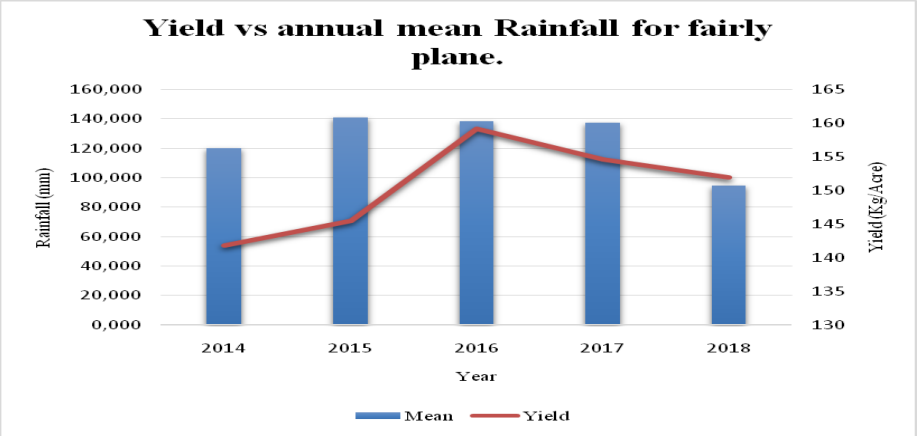


Figure 11: Yield vs Rainfall for fairly plain site

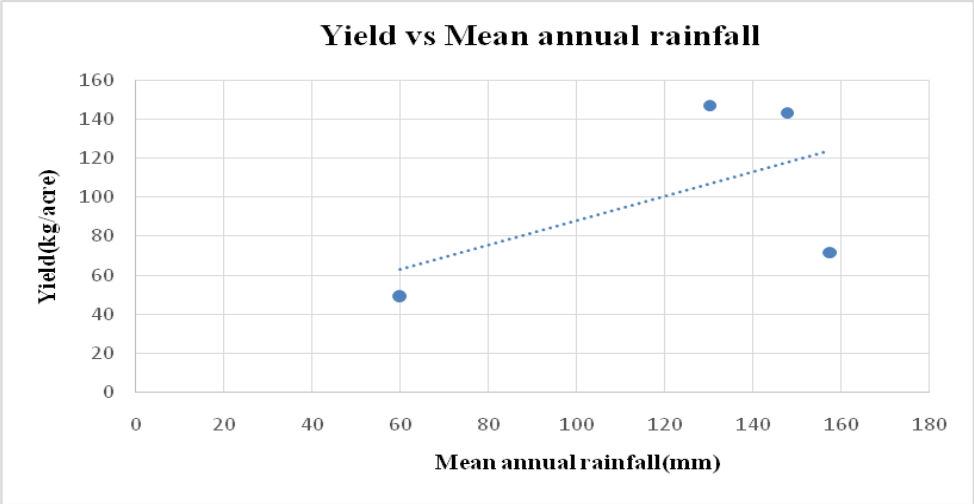


Figure 12. Mean yield vs. mean annual rainfall of four years

Table 4.Correlation between yield and mean annual rainfall for different Dzongkhag.

Year	Sarpang		Dagana		Samtse		Trongsa		Zhemgang	
	Yield (Kg/Acre)	Mean	Yield (Kg/Acre)	Mean	Yield (Kg/Acre)	Mean	Yield (Kg/Acre)	Mean	Yield (Kg/Acre)	Mean
2014	130	325.85	164	102.325	250	342.643	72	103.908	168	117.575
2015	167	438.367	150	116.258	242	465.458	63	121.492	66	129.617
2016	200	447.842	333	108.733	247	428.15	167	114	98	130.583

2017	121	494.192	135	95.625	224	497.367	51	130.6	52	113.233
Correlation	-0.832		0.221		-0.936		-0.884		0.767	

Potential Evapotranspiration (PET) for Pemagatshel was analyzed for 2016 and 2015.
Penman's Equation for computing Potential Evapotranspiration per day is based on the energy-balance and mass-transfer approach and it is given as:

$$PET = \frac{AH_n + E_a Y}{A + Y}$$

Where, PET = daily evapotranspiration in mm per day
A = slope of the saturation vapor pressure vs temperature curve at the mean air temperature, in mm of mercury per ^{0}C
H_n = net radiation in mm of evaporable water per day
E_a = parameter including wind velocity and saturation deficit
Y = psychrometric constant = 0.49 mm of mercury /^{0}C.
The net radiation is the same as used in the energy budget and is estimated by the following equation:

$$H_n = H_a(1 - r)\left(a + b\frac{n}{N}\right) - \delta T_a^4(0.56 - 0.092\sqrt{e_a})(0.10 + 0.90\frac{n}{N})$$

Where, H_a = incident solar radiation outside the atmosphere on horizontal surface, expressed in mm of evaporable water per day (it is the function of the latitude and period of the year)
a = a constant depending upon the latitude ϕ and is given by a = 0.29cos ϕ
b = a constant with average value of 0.52
n = actual duration of bright sunshine (it is the function of latitude)
N = maximum possible hours of bright sunshine
r = reflection coefficient (albedo) = 0.35
δ = Stefan- Boltzmann constant = 2.01*10^{-9}
T_a = mean air temperature in in degree kelvin = T +273
e_a = actual vapor pressure.

$$E_a = 0.35(1 + \frac{u_2}{160})(e_w - e_a)$$

Where, u_2 = mean wind speed at 2 m above ground in km/day
e_w = saturation vapor pressure at mean air temperature in mm of mercury.
The value of n is assumed a 6 hours and wind velocity was taken as 48 km/day and 44 km/day for 2016 and 2015 respectively. The latitude was taken as 27.04^{o}N and relative humidity is obtained from weather and climate of Bhutan(*Royal Government of Bhutan Climate Data Book of Bhutan*, 2018).
The various parameters A, H_a and N are calculated from the Table 3.3, Table 3.4, and Table 3.5 provided in Engineering Hydrology (Subramanya, 2013). The runoff volume was computed using SCS-CN method.

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}, \quad P \geq 0.2S$$

$$Q = 0, \quad P \leq 0.2S$$

Where
P= daily rainfall
Q=daily runoff from the catchment

$$S = \frac{25400}{CN} - 254$$

The curve number CN is obtained from Table 5.6(a) for Antecedent moisture content-II (AMC-II) of Engineering

Hydrology(Subramanya, 2013). The CN is therefore adopted as 80 and 84 for gentle slope and fairly plane gradient.

Hydrologic budget for the catchment in a given period of time, is given by:

$$P - R - ET_{act} = \Delta S$$

Where, P = daily rainfall
R = runoff
ET_{act} = actual evapotranspiration
ΔS = change in moisture content of soil

The moisture content was analyzed for the two study sites for 2016 and 2015 considering the same characteristics and properties of the soil which includes texture, hydraulic conductivity or permeability and the porosity. Also same temperature, same catchment area and same vegetative cover is considered.
ET_{act} is taken as the PET by assigning the crop coefficient k as unity.

Conclusion

The equation of the straight-line regression between the annual yield and the annual mean rainfall for the four years 2014, 2015, 2016, and 2017 of Bhutan are respectively Y = 0.464M + 37.881, Y = 0.45M + 2.581, Y = 0.05M + 158.86, Y = 0.007M + 50. Their respective correlation is 0.54, 0.69, -0.04 and -0.11. The straight-line regression between the annual yield and the annual mean rainfall for the study site of lesser slope site is Y = 0.057M + 143.25 and that of the gentle slope site is Y = -0.02M + 146.72. The respective correlation is 0.04 and -0.44. The amount of rainfall affects the yield moderately high for the first few years when the crop is still fresh. However, as the year progresses and the Cardamom ages the water rather hampers its yield. The correlation is negative where there is increase in rainfall pattern. There is maximum yield in 2016 where the corresponding mean annual rainfall is 147.821 mm. The change in soil moisture content is 34% for the labelled site that of the gentle slope site is 0 (as $P \leq 0.2S$) in 2016 where wind velocity was taken as 48 km/day and that of 2015 is 9% and 0 where the wind velocity was assumed as 44 km/day respectively. In 2014 PET is found to be more than daily rainfall because of the assumed data. The moisture content of soil is increased by 34% for the labelled catchment after the consideration of property of the soil for two catchments to be similar. The decrease in yield is due to excess of water content in soil.

Plant needs water for carrying nutrients and for the photosynthesis. An optimum amount water is required for maximum production of cardamom. The overall production Cardamom was maximum for 2016 in Bhutan as well as for the study site with total annual rainfall of 35477.2 mm and 1659.0mm respectively. The fairly well distributed rainfall yield is proportional to the water content up to certain limit, then the yield decreases even after the increase of water content. Although there are factors that accounts the production of cardamom such as pest and diseases, temperature, climate change, poor management, soil fertility and properties (Texture, porosity, and hydraulic conductivity) etc., water content is no less in the contribution of cardamom production. The production of Cardamom depends not only on the cultivated land with provided shade but also the gradient of the cultivated land.

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