APRIL 2020

DISCUSSION PAPER SERIES NO. 2020-09

Development of Crop Climate Calendars for High-Value Crops in Atok, Benguet: Report from Preliminary Co-Learning and Co-Development Engagements with Agricultural Stakeholders in Benguet Province

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April 2020

Abstract

Crop climate calendars augment traditional crop calendars by not only specifying planting and harvest schedules but also describing phenological states, cultivation practices and weather and climate requirements that any crop faces throughout a cropping season. The case to document this information in Benguet is compelling: The mountainous province experiences a unique microclimate and phenomena such as frost and hail and derives income from the cultivation of high value crops such as carrots, cabbage and potatoes amidst this. The researchers conducted focus group discussions with the municipal agriculturalists and farmer leaders in Atok, Benguet to understand their experiences and from there construct their crop climate calendar. The calendars produced in this exercise may serve as a solid foundation for the analysis of the community's climate-sensitive agricultural decisions.

Keywords: crop climate calendar, high value crops, weather and climate information, decision analysis, agriculture

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Development of crop climate calendars for high-value crops in Atok, Benguet: Report from preliminary co-learning and co-development engagements with agricultural stakeholders in Benguet Province[1]

Sonny N. Domingo, Anna Jennifer L. Umlas, and Katrina Mae C. Zuluaga[2]

Introduction

Linking the influence of weather and climate information to the decision alternatives available to farmers is an important facet of understanding climate resilient agricultural systems. Literature supports that many operational and tactical decisions such a crop choice, pesticide application and greenhouse construction are most successful when hinged on understanding how weather phenomena may shift schedules, yields, costs and incomes: For instance, as cited by USAID (2013) Letson et al finds that using ENSO forecasts to time planting and adjust irrigation increases value per hectare for both Argentinian landowners and tenants to $1.8 and $15 respectively. Likewise, Meza and Wilks show that value per hectare on Chilean potato farms increased $5 to $22 by using climate information to manage fertilizer.

That being said, this success is reliant on a thorough and well-informed decision analysis process. The process proposed by the ACIAR in its previous releases begins with the identification of climate-sensitive decisions which may then be taken into verbal, and then numerical decision analysis if applicable. This paper aims to outline the creation of crop climate calendars as one of the first steps in this decision analysis, where the calendar identifies and documents the weather and climate risks faced throughout the cultivation of cabbage, carrots and potatoes in Atok, Benguet.

What is a Crop Climate Calendar

A crop climate calendar is a visual tool that presents the phenology and cultivation practices of a crop against the timeline of the cropping season, and unlike a traditional crop calendar also contains information on the weather and climate states that occur in the locality and the risks faced by the crop per growing stage in relation to these.

In the Philippines, traditional crop calendars are often available through the municipal agriculturist's office for the crops planted in their area. The information in these calendars, which often contain only the dates for planting and the dates for harvesting, is usually sourced from farmers. Variations and augmentations of traditional crop calendars are available through a number of non-government and research organizations, but are more common for staple crops such as rice and corn.

The case to create crop climate calendars for Atok, Benguet in particular is compelling: Benguet's high elevation makes for a unique climate, moreover where a vast agricultural community relies primarily on rainfall to propagate crops. With the province's highest point, Mt. Pulag, located 2,922 meters above sea level, Benguet experiences much colder

[1] This paper is part of the preliminary output for the project, "Action ready climate knowledge to improve disaster risk management for small holder farmers in the Philippines", funded by the Australian Centre for International Agricultural Research (ACIAR). This project is a partnership among the following institutions—South Australian Research and Development Institute, Charles Sturt University, Department of Science and Technology – Philippine Atmospheric, Geophysical, and Astronomical Services Administration, Philippine Institute for Development Studies (PIDS), University of Philippines Los Baños, Department of Agriculture – Agricultural Training Institute, and Benguet State University.
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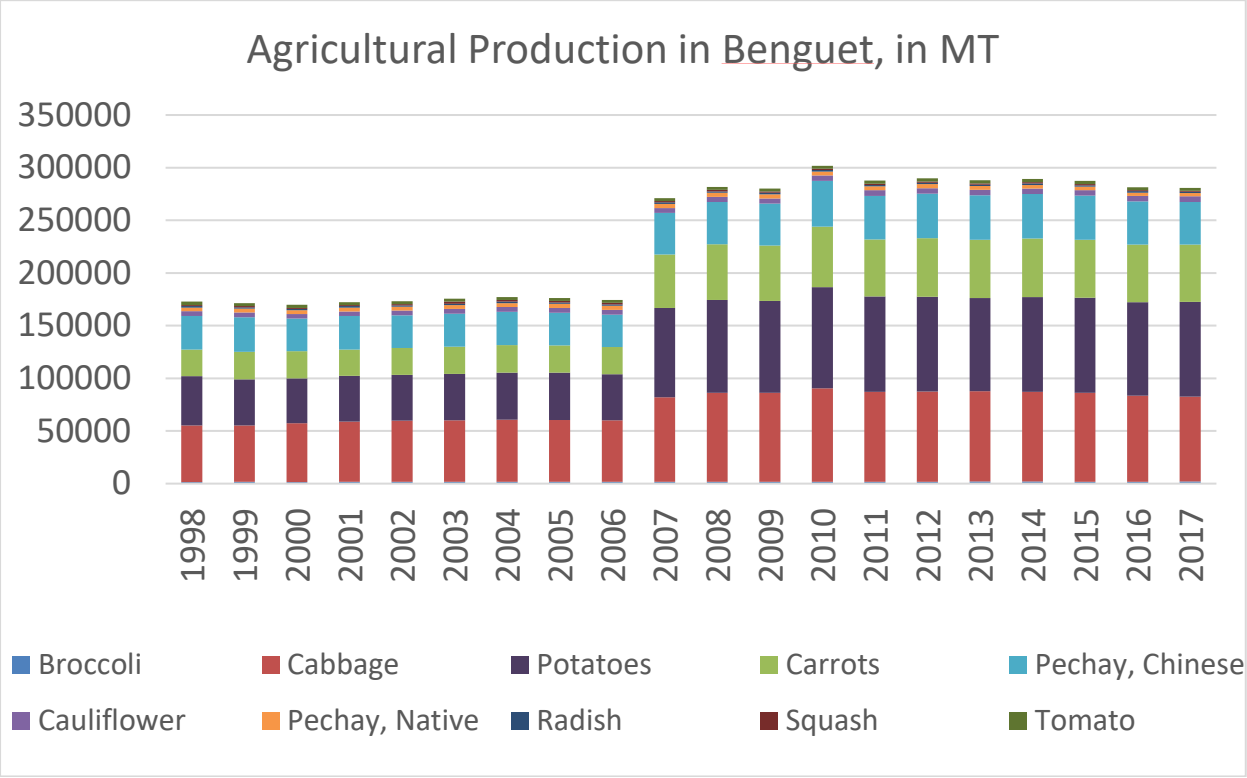
temperatures than the rest of the country with an average low of 8.6 degrees Celsius in January and a high of 26 degrees Celsius in April. The Corona's System of Classification further categorizes Benguet as a Type I climate, with distinct wet and dry seasons that begin in May and November respectively. It is in this climate that Benguet produced close to 33 percent of the Philippines' high value vegetables, and close to 74 percent of the country's cabbage, carrots and potatoes in 2017(PSA 2018). Despite this, however, farmers report a growing lack of distinction between the traditional wet and dry season, challenges in implementing irrigation and pest control, and unique phenomena such as frost, indicating the need to better document and understand the role of weather and climate in the farming season.

Figure 1. Agricultural production of select high value vegetables in Benguet in from 1998-2017. This shows that cabbage is historically the most produced vegetable in Benguet, followed by potatoes and carrots.



Source: PSA, 2018

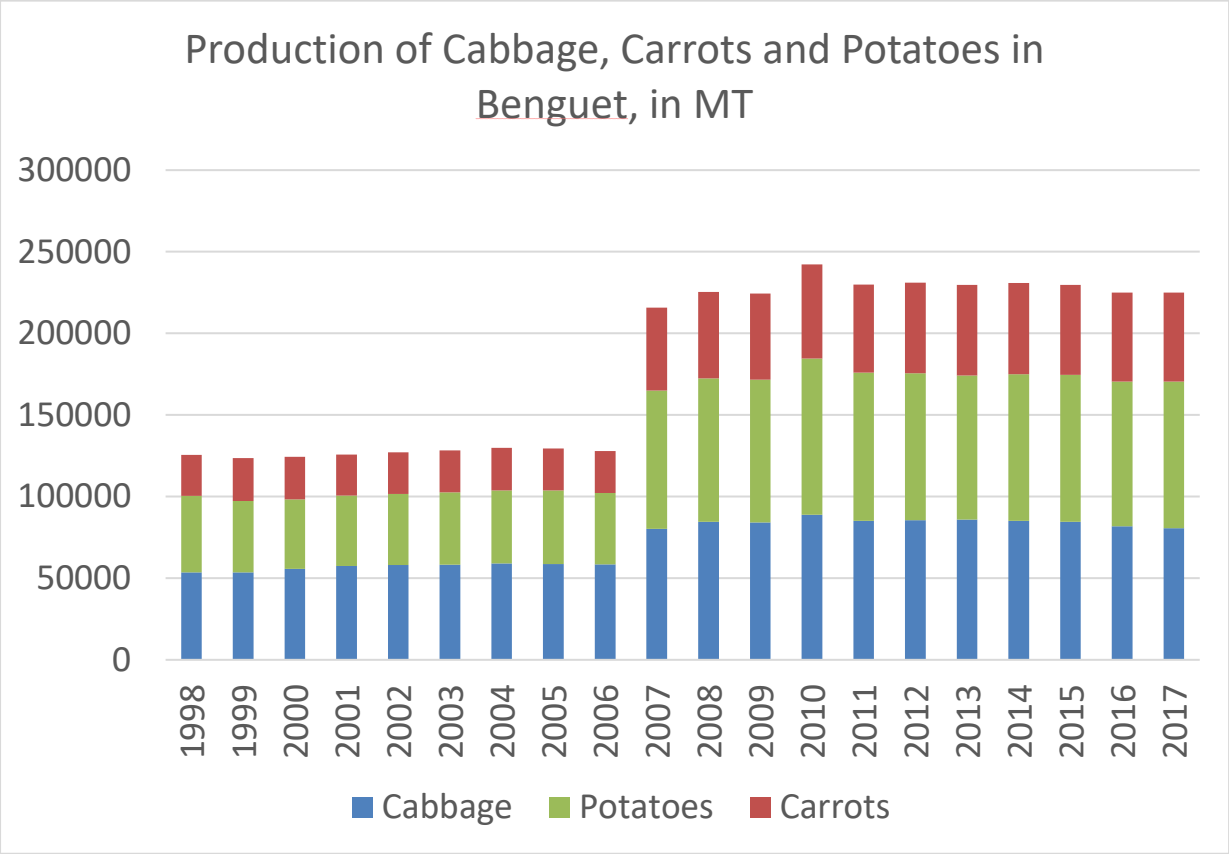
Table 1. Benguet production of select high value vegetables as a share of total. Benguet produces close to 33% of high value vegetables in the Philippines.

Production of select high value vegetables, 2017 (in MT)	
Philippines	853,559.3
CAR	317,129.8
Benguet	280,683.0

Share in Total Production, 2017	
CAR share in PH	37.15%
Benguet share in PH	32.88%
Benguet share in CAR	88.49%

Source: PSA, 2018

Figure 2. Production of cabbage, carrots and potatoes in Benguet in MT. Benguet produces consistently high levels of these three vegetables year on year.



Source: PSA, 2018

Table 2. Benguet production of cabbage, carrot and potato as a share of total. Benguet produces close to 89% of these vegetables in the Philippines.

Cabbage, Carrot and White Potato Production, 2017 (in MT)	
Philippines	305,330.8
CAR	252,975.2
Benguet	224,913.6

Share in Total Production, 2017	
CAR share in PH	82.85%
Benguet share in PH	88.90%
Benguet share in CAR	73.66%

Source: PSA, 2018

Background of the Project

This undertaking is part of the project Action Ready Climate Knowledge to Improve Disaster Risk Management for Smallholder Farmers in the Philippines. The project overall aims to improve the value of information flows between the country's mandated weather and climate information provider the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and key decision makers in the management of weather and climate risks of smallholder farmers. Specific objectives under this overarching theme include:

1. To understand current status of DRR and CCA for small holder farming in study sites
2. To analyze the potential and realized value of weather and climate forecasts for at least nine decision contexts
3. To develop pilot communication material and scale-up the project findings to other LGUs and farming groups

In achieving these objectives, prior papers in this series have already detailed the climate-sensitive decisions of famers, local government and vegetable traders in Atok, Benguet. Beyond these there have also occurred activities assessing the potential value of additional or improved weather and climate information through decision analysis, as well as those identifying the barriers to the access and use of this information. Next steps then include outlining the paths to effectively communicate this information to those who need it most, through both a social network analysis and the development of the KlimAgrikultura training module for agricultural extension workers.

The study has taken to focusing on change agents in particular as a means of understanding and disseminating weather and climate information, and thus consider them key stakeholders in the KlimAgrikultura module. The module aims to be slotted into the Agricultural Trainining Institute's existing modules on climate smart agriculture, and will introduce decision making processes and decision making tools such as the crop climate calendar and the Excel-based Rapid Climate Decision Analysis (RCDA) for the preliminary use of Benguet's 141 agricultural extension workers, many of whom interact directly with farmers on the field. While farmers and extension workers alike are to an extent already aware of their weather and climate risks, there is value in furthering this and being able to connect each risk to specific PAGASA weather and climate products to facilitate the access and use of the information. In this vein, the pilot module will be documented, formalized and scaled up to other LGUs and localities. It is expected that there will be economic benefits that result from streamlining the use of weather and climate information.

Role of the Crop Climate Calendar in Extension Work

Thus, the crop climate calendar is meant to a be a decisionmaking tool that is both concise and comprehensive. Its strength is that it lays out in one place a myriad of concerns farming stakeholders may have over a cropping season, making it quicker to both find specific concerns and consider multiple concerns with respect to others. It can be a strong springboard for a more thorough analysis of a risk or climate-sensitive decision as well, especially with the inclusion of ranked risks and guidance on the PAGASA weather and climate product relevant to the issue. For the agricultural extension worker, this may be a useful tool in the facilitation of the decision analysis process, and the illustration of the interface between weather and climate information and farming systems.

Identified Climate Sensitive Decisions

Climate sensitive decisions are decisions that hinge on weather and climate states, with final outcomes and even decision alternatives changing depending on the prevailing weather phenomena. On the farm these decisions are plentiful, ranging from when and what to plant, to when to harvest and bring the crops to market. Other stakeholders in the agricultural value chain, such as local government units as well as traders and disposers, may also need to make decisions considering the weather and climate.

For farmers, weather and climate decisions may span a single day (operational), cropping season (tactical) or many more (strategic). Common tactical decisions include crop choice: For instance, potatoes are more suited to drier weather, while cabbages are preferred during wet weather. From there, the timing of the onset of rainfall will determine when farmers will begin to prepare their land and sow seeds or transplant seedings; usually, land preparation begins a month in advance of the onset of rainfall, while sowing and transplanting begins two weeks after that. Maintenance of the plant throughout the cropping season is also reliant on the amount and schedule of rainfall. Cabbages are sprayed more during the dry season as this is when pests are prevalent, while potatoes and carrots are sprayed more during the wet season as this is when they are affected by diseases such as blight. Strategic decisions, on the other hand, encompass decisions like the installation of rain shields, greenhouses and irrigation, whose effects can be felt beyond one cropping season. The decision of installing irrigation is a particularly interesting one: All other things accounted for, though the initial capital expenditure for the system is high and potentially lossmaking in a wet season where the system is not needed, there still exist opportunities to recoup the costs of the system in any succeeding situations of unpredictable or inadequate rainfall where the system can help guarantee more consistent yields.

Figure 3. Table of select climate sensitive decisions in farming

Activity	Forecast	Response
crop choice	drought or below normal rainfall	- plant drought tolerant crops such as potatoes or radish
choice of crop variety	dry season	- cabbage: scorpio variety
	wet season	- cabbage: rareball variety
source of irrigation	drought	- use of water delivery services
occurrence of frost	no frost forecast	- do not plant in identified frost-occurring areas in the farm; - plant crops that can tolerate cool temperatures such as carrots or cabbages - use sprinklers in the morning to melt the ice
harvesting	occurrence of typhoon	- use rain shields to protect the crop - consult with disposer and check if crop is suitable for early harvest

Source: (x, 2018)

Other stakeholders in the agricultural value chain face climate-sensitive decisions usually considering severe weather. Truckers and disposers, for example, might choose not to take produce during seasons of heavy rainfall to reduce the risk of loss of produce or accident on the road, especially given that Benguet is prone to landslides. Beyond this, the local government unit (LGU) must also have protocol to disseminate weather warnings, and then mobilize disaster risk reduction officers and enact contingency plans. Seasonal climate forecasts and ENSO advisories, however, are also important to the LGU and local agriculturist offices, who may have to structure irrigation assistance programs, information drives and further training around the coming needs of their constituents.

Figure 4. Table of select climate sensitive decision in agricultural value chain

Decision makers	Forecast	Response
LGU/institutions	El Nino forecast	- distribute irrigation infrastructure - deliver water to drought hit areas
	La Nina forecast	- Send advisories by SMS
	Typhoon forecast	- Send typhoon warning advisories
Truckers, value-chain	Typhoon forecast	- delay transport - transfer to unaffected market - reduce quantity of vegetables purchased

Source: (x, 2018)

Preparation of Crop Weather Calendar

1.1. Collection of data

The data was obtained through both desk research and field engagements with the municipal agriculturists office and the farmers in Atok, Benguet. Initially, the traditional crop calendars were obtained from the Office of the Municipal Agriculturist of Atok to determine the basic cropping schedule there, and from then expanded to include phenological stages and pertinent weather and climate risks.

The phenological stages listed for each crop are based on agricultural science literature and crop production manuals available from the academe, research institutions and private agricultural corporations. These growth stages, as well as the primary requirements for crop growth, were validated by the Municipal Agriculturist and farmers during discussions.

The initial set of weather and climate risks also originated from similar resources and were added to by the Municipal Agriculturist and farmers during focus group discussions. These were further validated by each party through a second and third set of discussions.

Three rounds of discussions on the climate-sensitive decision analysis tools have taken place so far. The first set of discussions, which involved the municipal agriculturist and 3 other municipal agriculturist officers, took place in July 2019 in Atok, Benguet and elicited the first data on planting costs, commodity prices, planting schedules and weather and climate risks. The second set of discussions were with 7 farmers of cabbage, carrots and potatoes that took place in October 2019 in Atok, Benguet, and elicited the majority of the weather and climate risks per crop per growing stage that are included in the crop climate calendar. This discussion also gave more color on local cultivation practices such as sharing of labor during hilling up and weeding, the prevalence of pesticides and fungicides in the area plus its indicative costing, and drivers behind these practices and other climate-sensitive decisions. The team returned to Atok validate the farmers' answers with a group of 5 municipal agriculturist officers, the municipal agriculturist, one municipal disaster risk reduction and management officer, and one farmer in November 2019. This is indeed an iterative method that emphasizes co-learning and co-development of the crop climate calendar and the RCDA decision making tools.

Crop cultivation environment in Atok, Benguet

1.2. Changes in rainfed agricultural system

Farmers reported a difference in PAGASA's data versus their experiences on when the rainy season is. While farmers say they experience rain all year round now and do not distinguish between wet and dry seasons anymore, PAGASA's analysis of both 30-year and 5-year averages of rainfall levels show that the rainy season still distinctly begins in March.
Farmers believe PAGASA's data is more consistent with what they used to experience in the 90s, before they claim the climate changed. Now, they state that March to May would be a dry season, while June would be the start of rainy season without typhoons, and August the start of typhoon season. Now, moreover, farmers plant whenever they feel they can plant, saying that farming is much like gambling. They often begin planting in March, though, to take advantage of June rains and be able to harvest before the typhoons come in August. However, some farmers take the risk of planting and harvesting around August, where they know the supply of vegetables will be lower and prices will be higher. This is true for planting carrots

and potatoes particularly since they can less be affected by the typhoons as root crops, and the harvest will be in time with the rise in vegetable prices just before the December holidays.

It was discussed that the disparity in PAGASA's estimates and Atok's experiences could likely stem from the El Nino as well as the lack of localized data. Per PAGASA, El Nino actually brings in more rains to Benguet province. The data they are using, however, is from their weather station in Baguio or La Trinidad. The automatic weather station in Atok has not yet produced enough data to be analyzed, and sometimes cannot transmit data if it does not have enough load to do so.

1.3. Irrigation

Irrigation allows a farmer to plant near any time of the year, though because of the scarcity of water source, it is rare for a plot to be fully irrigated in Atok. Irrigated farms can have up to 3 cropping seasons while rain-fed farms only have one or two cropping seasons that are March-June/July and October to December. Despite this, farmers estimated also that only 1 in 4 farmers hold irrigated lands. Beyond the scarcity of running water sources, irrigation is also challenging given the pipes crossing private lands and long distances, the high costs of such systems, and instances of the National Irrigation Administration giving systems that are inappropriate for highland farms.

1.4. Measuring rainfall

Farmers in Benguet do not measure their rain in millimeters, rather, they measure it in days or times a week; thus the decision on when to plant depends on when they believe the rains will start coming regularly and consecutively. The date targeted is at most one month before it starts to rain more often. The farmers also prefer the afternoon rains that Atok experiences outside monsoons and typhoon season.

While it was not fully articulate how much rain is considered enough, the farmers were able to express how much was clearly too much. The farmers are averse to monsoon rains, where rain falls continuously (but not too hard) for close to 24 hours. Seven days of monsoon rains were deemed sufficient for their plants, but 15-20 days of monsoon rains will definitely cause the crops to fail. Drainage is also a big consideration in how long certain crops will last in monsoon rains.

The farmers are in fact more averse to monsoon than typhoons. Typhoons may flatten some crops in the three days they pass through Atok, but will not rot them like monsoon rains do.

1.5. Frost and Hail

Frost is no surprise to the farmers, though it is a phenomenon unique to a few parts of Benguet. Farmers know when it will occur (January and February), and which areas of their farms will be affected. To cope with this, planting is avoided those areas during those times. It is also possible to choose to plant carrots, which sustains less frost damage, or time the growth of cabbages so the damage sustained to leaves is minimal. Potatoes, on the other hand, are susceptible to frost. The farmers emphasized that despite these challenges, however, frost is not that big of a problem to them and is only sensationalized by the media.

Hailstorms may occur after frost does, usually in April or May. Specifically, the farmers have grown to expect hail when the frost does not come, though the MAO states that this is not the criteria for occurrence of hail. Hail deals physical damage to crops, which is more problematic

for cabbage plants than root crops and also depends on the size of hail. More often, the sizes are small and are not damaging to be of concern. However, if the sizes are too big and can cause damage, the MAO said there is little that the farmers can do to protect their crops but to avail crop insurance. Even greenhouse or crop covers are not sufficient because severe hailstorm can damage the roof and covering.

1.6. Calendar spraying

The farmers were able to identify the types and prices of different chemicals they mix into a "cocktail" to spray on the crops as well the number of applications needed per season. The cocktail mixing and scheduled ("calendar") spraying is against the advice of the Municipal Agricultural Office (MAO) and the Department of Agriculture (DA). They are also aware that use of fertilizer increases with the "abuse" of their lands; i.e. when planting continuously and not allowing lands to fallow or recuperate. More than government agricultural extension workers, the farmers are visited by technicians and sales representatives from private agrichemical companies who also help them learn these things.

1.7. Forecasting experience

Farmers are familiar with both technical and indigenous forecasting methods. For instance, they specified that they research the schedule and effects of the El Nino period. They also tend to blend modern and traditional forecasting methods to decide when and where to irrigate. Furthermore, they understand that their indigenous forecasting methods are often rooted in science: They spoke of a specific dragonfly only appears a certain time of year and heralds the rainy period, and specified that it was likely because the dragonfly's lifecycle coincides with the rainy period and the conditions in the environment at that time. They also considered that maybe the birds they spot to belay particular seasons are probably migratory, and appear when they leave colder climates or other weather conditions behind.

1.8. Crop programming

The crop programming scheme in Atok was never formalized nor implemented. Its promotion has been limited to IEC materials. The farmers recognized, however, that it might be better if all farmers in Atok followed the scheme, which they understand would lead to less fluctuations in prices; however it has been much different in practice.

Crop cultivation practices documented in the crop climate calendar

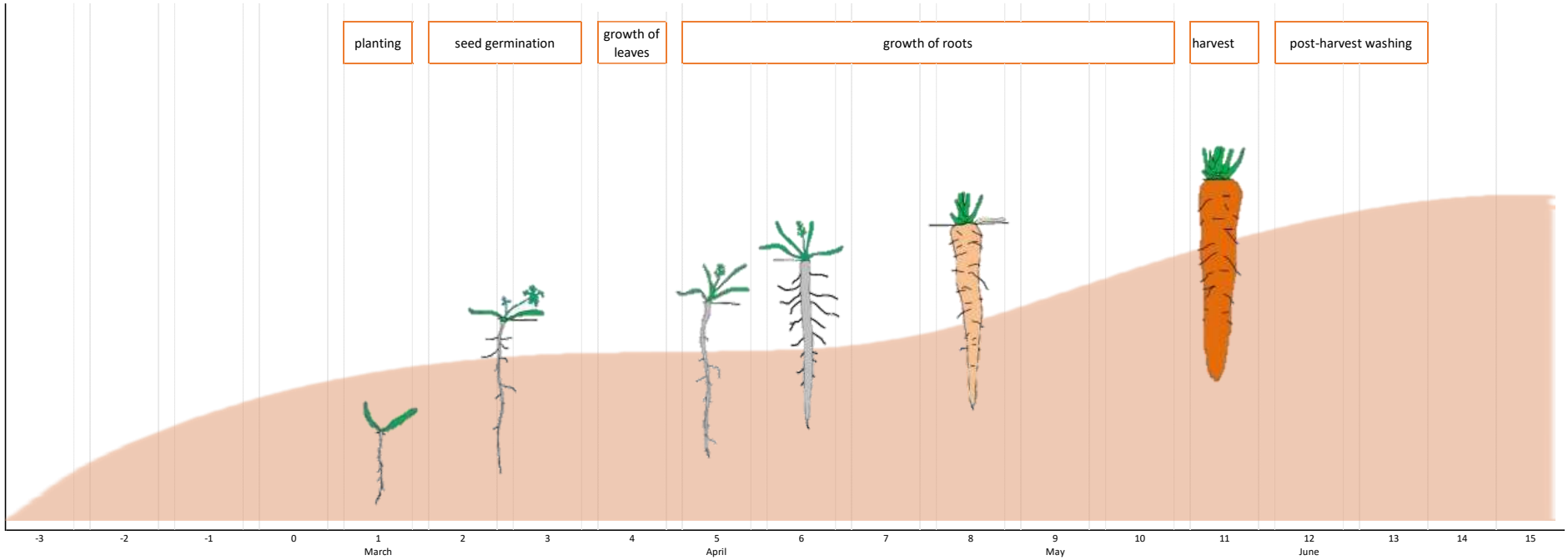
1.9. Carrot

Figure 5 (enlarged in the Appendix) presents the growth stages of carrots. On the x-axis would be time expressed in weeks, where the planting season begins in March (after land preparation in the month before that) and ends with the harvest in June. Alternatively, however, carrots may be preferred in the drier cropping season later in the year, which is from October to December. This way, farmers can avoid root crop diseases commonly associated with the rainy season; on the other hand, they may encounter lower commodity prices characteristic of the holiday season, so this may a good example of a decision whose optimal alternative will be different for each and might be best approached through a systematic decision analysis process.

Radish is a very similar crop that has been gaining popularity in the area also on the back of rising market demand.

Of the different carrot varieties available in Atok, the MAO and farmers alike agreed that Terracotta is the most popular. Per the Department of Agriculture's (DA) carrot propagation guidelines, this variety has a high germination rate, is more resistant to diseases and pests, keeps for longer after the harvest and is generally good in any weather.

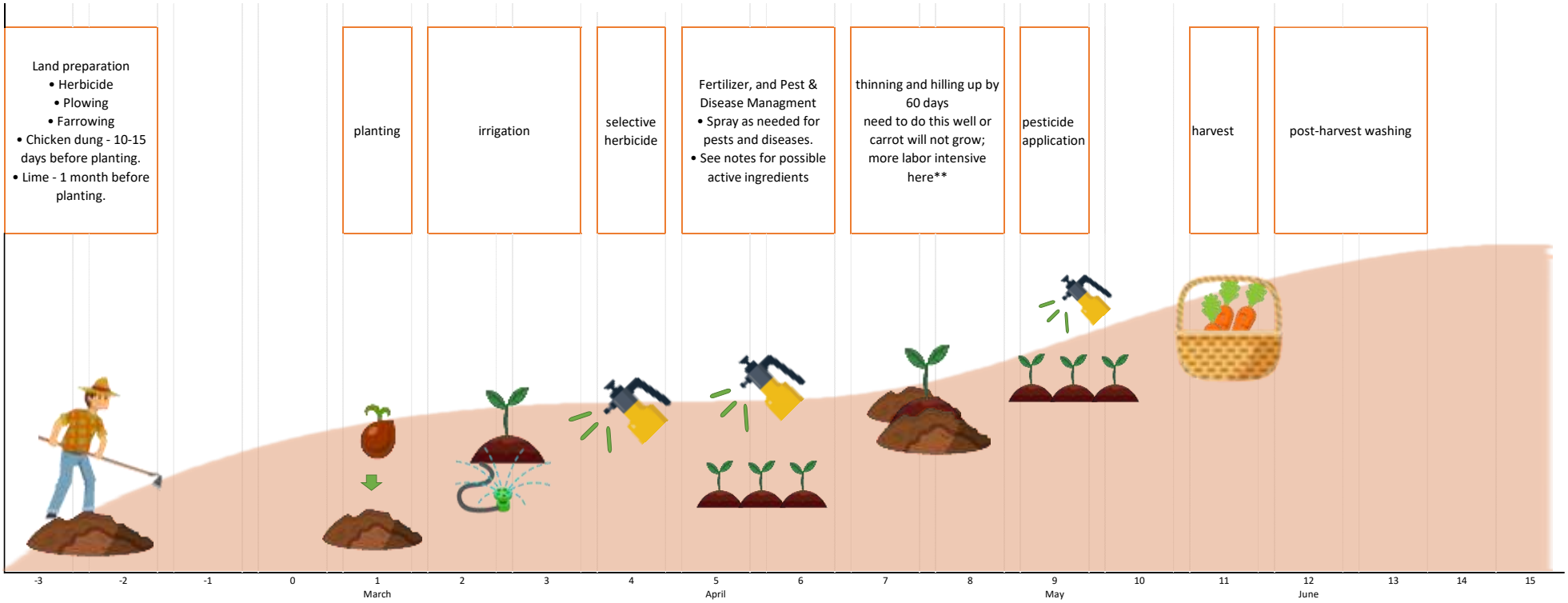
Figure 5. Growth stages of carrots. Adapted from online sources and discussions with farmers.



Beyond this, Figure 6 (enlarged in the Appendix) presents the cultivation practices for the carrot crop. Overall, carrots require less inputs but more labor than cabbages and potatoes, which is an important consideration for crop choice as well. Land preparation for carrots includes herbicide, farrowing, the application of chicken dung up to three weeks before planting, and lime at least a month before planting to neutralize components of the soil that disease-causing nematodes. Following this, carrots are directly seeded, and can be planted closer together than other crops; they are, however, prone to forking and deforming in rocky and heavy soil. Throughout their development, the soil must be loose, moist and weed-free. In Atok, weeds are eliminated though hilling up, where they cover the weeds with soil as well. Thus thinning and hilling up are important but labor-intensive practices that occur around 60 days after planting, and require roughly 100 man days per hectare to complete.

The carrots are no exception to the calendar spraying and chemical cocktailing that farmers in Atok practice against the DA and MAO's recommendations. Common active ingredients in this cocktail are Cymoxanil, Chlorothalonil, Lambda cyhalothrin and foliar fertilizer where the former two are for blight, and the latter for aphids and beetles and fertilization, respectively.

Figure 6. Cultivation practices of carrots. Adapted from online sources and discussions with farmers.

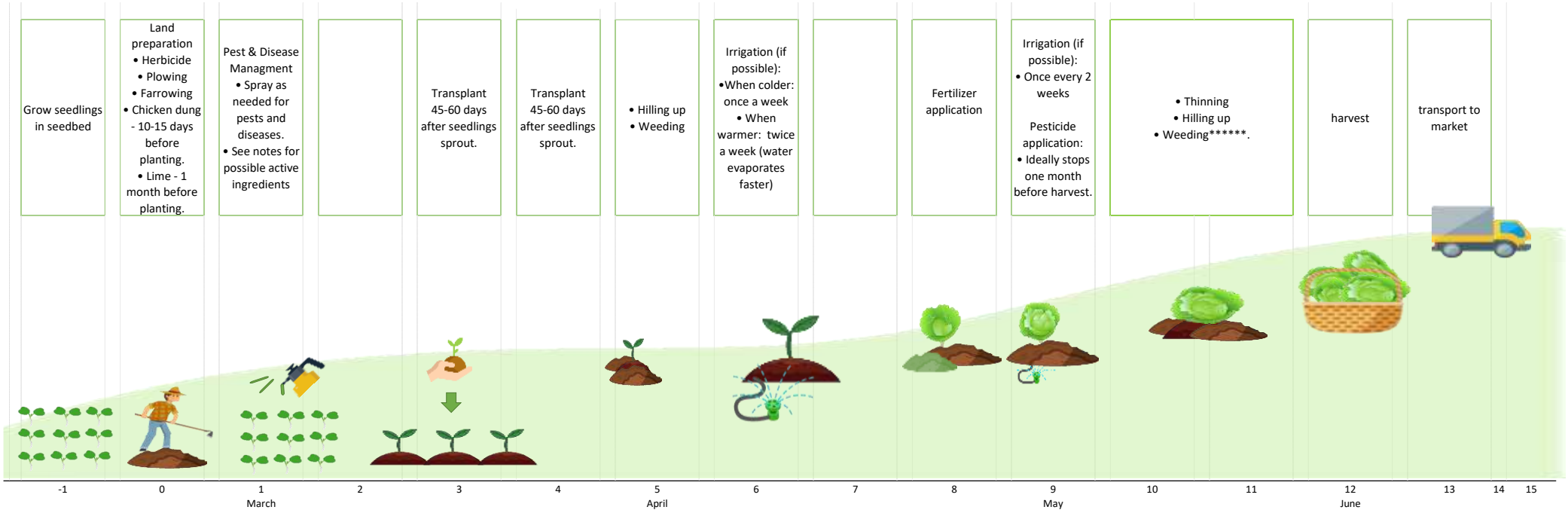


1.10. Cabbage

Figure 7 (enlarged in the Appendix) presents the growth stages of cabbage. Cabbages are planted in March. In March of the succeeding year, they are usually rotated out in favor of carrots to avoid the spread of diseases. Moreover, cabbages cannot be planted during typhoon season as they will get swept away. While when successful, cabbages bring in large yields, they have high input costs and are not hardy crops. The nematodes that cause club root among other diseases are more prevalent in warmer weather.

In Benguet, the Scorpio variety that prefers colder temperatures is usually grown. This variety is also appropriate for drier seasons. The Rareball and Wonderball varieties are more resistant to rainy conditions, however, though in the validation round of discussions the farmers and MAO confirmed that temperature is the primary consideration for variety choice.

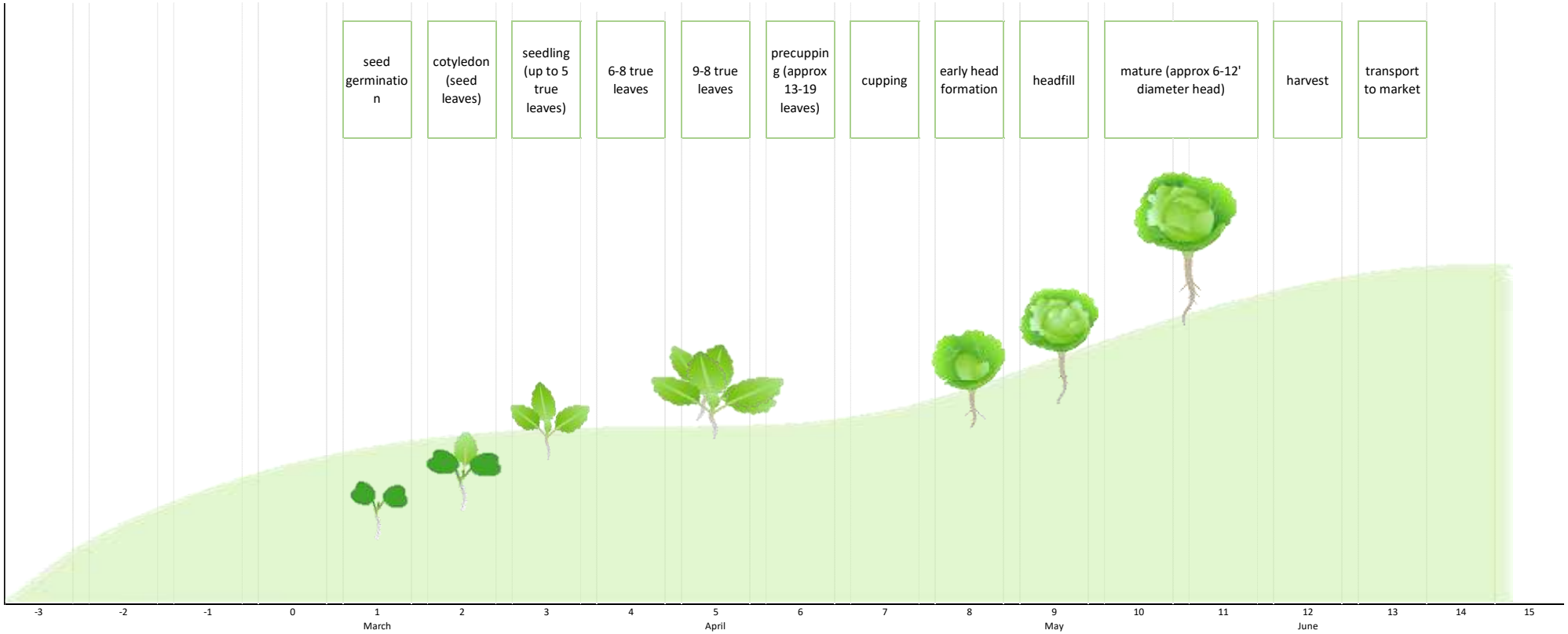
Figure 7. Growth stages of cabbage.



Adapted from online sources and discussions with farmers.

Figure 8 (enlarged in the Appendix) details the cultivation practices for cabbage. Seedlings are grown in a seedbed before being transplanted 45-60 days later. Common active ingredients used in the maintenance of the crop while growing are given in Table 3.

Figure 8. Cultivation practices of cabbage.



Adapted from online sources and discussions with farmers.

Table 3. Common insecticides, fungicides, bactericides and fertilizer used in propagation of cabbage.

Chemicals	Brand	Description
Chlorypyrifos	Lorsban	For worms and beetles
Difenoconazole	Score	Fungicide (alternaria and ringspot)
Copper hydroxide	Kocide	Fungicide and bactericide (black leaf spot and black rot), cannot be cocktailed
Foliar fertilizer	Peter's	Contains nitrogen, phosphate, etc
Green label biological insecticides		Diamond back moth
Spinetoram, Emamectin Benzoate	Radiant, Proclaim	Diamond back moth

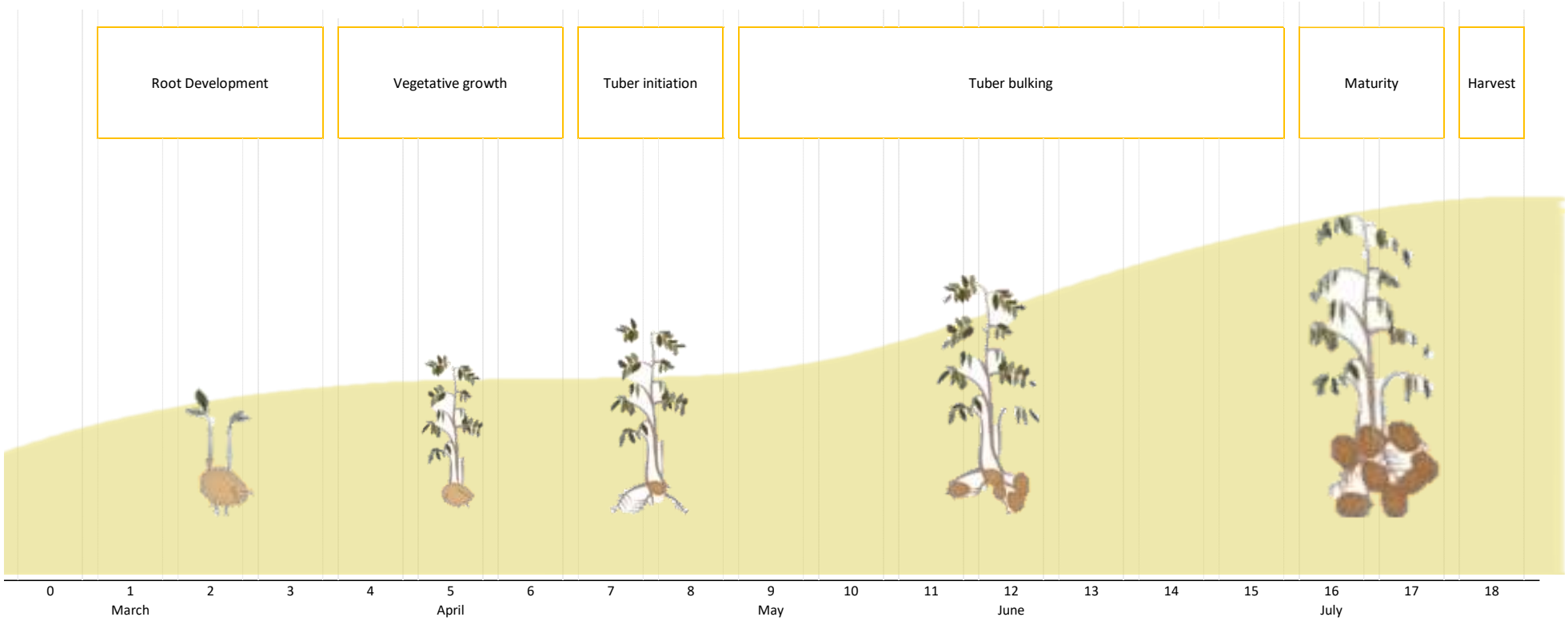
Adapted from online sources and discussions with farmers.

1.11. Potato

Figure 9 (enlarged in Appendix) shows the growth stages of potato against the timeline of the cropping season. Potatoes are planted in March and harvested in early July. They may also be planted in drier conditions later in the year, starting in October, as potatoes are also sensitive to accumulated rainfall.

While these crops are only planted every so often to reduce the risk of disease proliferation, planting potatoes also depends on the availability of seeds from sources like Benguet State University. Sometimes, seeds are queued up for, and are sold out even the planting season prior; there is great opportunity for profit for farmers who can make seed production their business. Thus seed availability also dictates choice of variety: Igorota variety seeds are easier to purchase in December, and Granola seeds are easier to purchase in March and April.

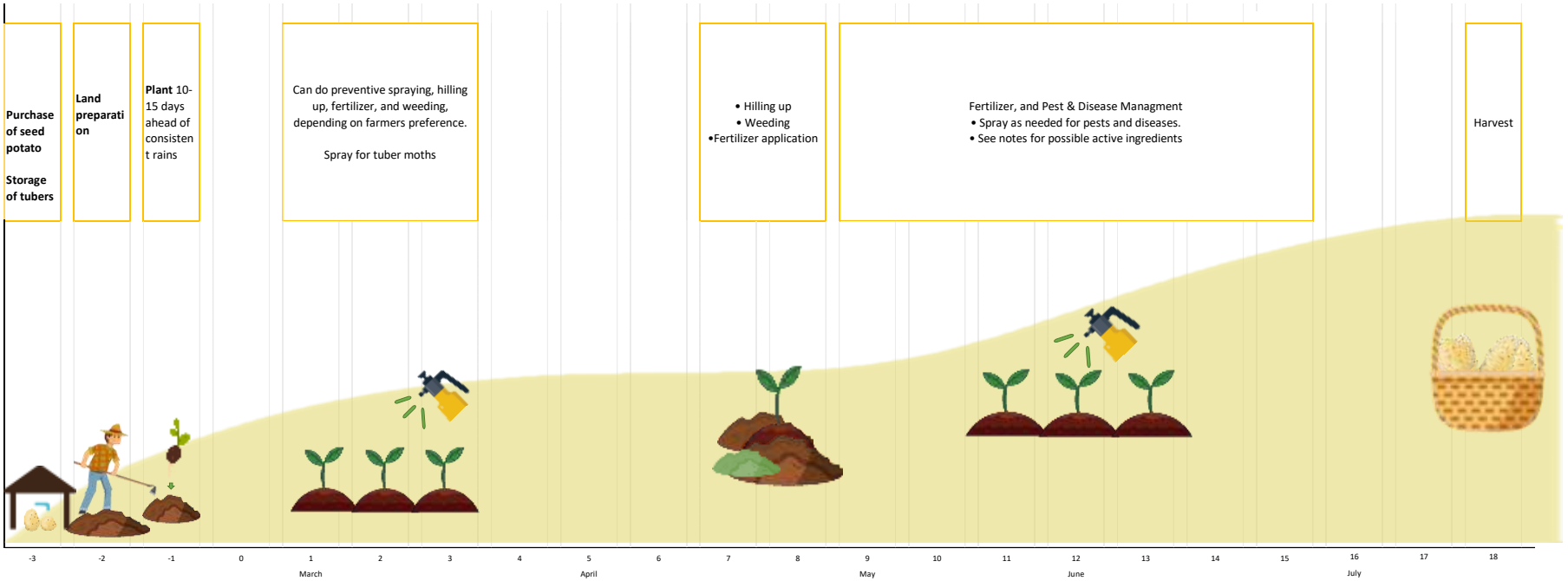
Figure 9. Growth stages of potatoes.



Adapted from online sources and discussions with farmers.

Seed potatoes are stored for two months (Igorota variety) to four months (Granola variety) before the sprouted tubers are planted. They are planted 10-15 ahead of consistent rains, and sprayed for tuber moths early on. Hilling up, weeding and fertilizer application are done seven to eight weeks into planting, during the tuber initiation stage. Hilling up also eliminates weeds when soil is piled onto them, and ensure that the growing tubers are not exposed to sunlight. Crop maintenance is again cocktailed and calendared against the DA's recommendations, with active ingredients similar to those for carrots shown in Table 4.

Figure 10. Cultivation practices of potatoes.



Adapted from online sources and discussions with farmers.

Table 4. Common insecticides, fungicides, bactericides and fertilizer used in propagation of potatoes.

Chemicals	Brand	Description
Cymoxanil	Curezate	Fungicide for late blight
Chlorothalonil	Daconil	Fungicide that helps control early and late blight, and botrytis gray mold.
Lambda cyhalothrin		Insecticide for aphids and beetles
Foliar fertilizer	Peter's	Contains nitrogen, phosphate, etc

Adapted from online sources and discussions with farmers.

Weather and climate risks vis-à-vis growing stages

The tables below summarize the crop climate calendars that are appended to this paper.

1.12. Cabbage

The main body of the crop climate calendar shows the weather and climate risks that cabbage crops face throughout its life cycle.

Primarily, this portion of the calendar shows that at any stage of growth, cabbages are sensitive to accumulated rainfall. Overall the crop requires an approximate 440 mm of water throughout the growing season, divided into 10-15mm weekly until week 6, and 25mm weekly during the cupping stage and onward (Starke Aryes, 2014). This follows how while seedlings need sufficient water in order to fully establish, too much water will wash away the seedlings. Moreover, too much water after germination will rot the crop. Beyond this, too much rain washes out the nitrogen in the soil that the cabbage needs. Some local responses to this are aging the seedlings up to 60 days to ensure their resilience in case of rains, or harvesting early to save from monsoon rains.

Farmers still plant cabbages in wetter seasons, however, as accumulated heat is associated with pests like diamondback moth, and diseases such as club root, caused by nematodes. This means the cabbages will have to be sprayed more often throughout the growing season, increasing both labor and input expenses.

Frost and hail damage are phenomenon unique to Atok. Cabbages are vulnerable to frost early after germination until head formation. Once the cabbage is more mature it becomes easier to simply remove the leaves that have been affected by frost. Hail occurs in April to May and causes physical damage to the crops; unfortunately, there is not much farmers can do about this.

Table 5. Crop climate calendar summary for cabbages.

Crop:	Cabbage					
Cultivation practices	Timing	Inputs	Description	Priority Weather and Climate Risk		
Grow seedlings in seedbed			Seedlings are aged 45-60 days after sprouting to be more resilient when planted			
Land preparation • Herbicide • Plowing • Farrowing • Chicken dung • Lime	10-15 days before planting 1 month before planting	 Chicken dung Lime	In practice, lime is added around the same time as chicken dung to reduce labor costs. This neutralizes soil acidity and controls nematodes that cause clubroot.			
Pest & Disease Management	Spray as needed for pests and diseases	Chlorypyrifos - fungus and beetles Difenoconazole - fungicide Copper hydroxide - fungicide and bactericide Foliar fertilizer- contains nitrogen, phospate, etc Green label biological insecticides- Diamond back moth Spinetoram, Emamectin Benzoate- diamond back moth	Cabbage is sprayed more in the dry season because pests are a bigger concern. Potatoes and carrots are sprayed more in the wet season because fungi and diseases are a bigger concern.	Accumulated heat: more pests, club root and nematodes	Typhoon: will blow crops around at any stage	
Transplant	45-60 days after seedlings sprout					Frost: young cabbages vulnerable to frost
Hilling up and weeding	Week 5		Weeding is taken care of through hilling up, when weeds are covered with soil.			
Irrigation	Week 6-Week 8 •When colder: once a week •When warmer: twice a week (water evaporates faster)	requires approx 10-15 mm per week until week 6	If possible			
Fertilizer application	Week 8	Foliar fertilizer- contains nitrogen, phospate,				
Irrigation	Week 9 •Once every 2 weeks	requires approx 25mm per week until harvest	If possible			
Pesticide application	Week 9 •Ideally stops one month before harvest.	Chlorypyrifos - fungus and beetles Difenoconazole - fungicide Copper hydroxide - fungicide and bactericide Green label biological insecticides- Diamond back moth Spinetoram, Emamectin Benzoate- diamond back moth				
Thinning	Week 10-11					
Hilling up and weeding	Week 10-11		Weeding is taken care of through hilling up, when weeds are covered with soil.			
Harvest	Week 12					

1.13. Carrot and Potato

As root crops, carrot and potato share many similar weather and climate risks. The farmers specified that both are susceptible to blight and similar diseases associated with wetter conditions; however, while carrots are more laborious, they bear significantly less risk of pests and diseases versus cabbage and potatoes. Despite this, both crops will also rot in too much rainfall or with the accumulation of standing water, and thus fifteen to twenty days of heavy monsoon rains were identified by the farmers to cause crop failure, even when a farm has adequate drainage. Carrots and potatoes are more resistant to typhoons as root crops, however, though farmers may still choose to harvest before typhoons or heavy rains occur to save the crops from landslides or standing water damage. For potatoes this means that Granola variety can be harvested early at two months and Igorota at three, though the produce will not achieve its maximum weight and size and are susceptible to scratching.

On the other hand, a deficit of water will also limit foliage development and subsequent tuber development in potatoes. Beyond this, roots and leaves will also be harder to form in hotter weather, and the potato plant will also attract more pests. Tubers that are also exposed to sunlight will turn green and poisonous and cannot be sold in the market, though may still be

suitable as seed potatoes later on. Still, though potatoes can be planted any time seeds are available, tubers become larger in drier seasons.

Carrots are also sensitive to higher temperatures and will produce long, pale and slender roots when it is too hot. The optimal range to grow carrots is 15.6-18.3 degrees Celsius.

Frost and hail damage to a potato, alternatively, will depend on the crop's stage of growth. Frost will kill potatoes less than three months old, or not yet at maturity stage. Otherwise, it is possible to control frost with a sprinkler and hilling up. On the other hand, potatoes are more resilient to hail damage earlier on in their life cycle, as this allows time for broken leaves to regrow in time to support tuber development.

Farmers also emphasized that once a potato begins to reach maturity, they are less worried of weather and climate risks and feel that they are guaranteed a crop.

Table 6. Crop climate calendar summary for carrots.

Crop	Carrots					
Cultivation practices	Timing	Inputs	Description	Priority Weather and Climate Risk		
Land preparation • Herbicide • Plowing • Farrowing • Chicken dung • Lime	10-15 days before planting 1 month before planting	 Chicken dung Lime				
Planting	10-15 days ahead of consistent rains	Usually requries 60 cansx100 g seeds for 1 ha		landslides: at any stage will cause the crop to be lost	Excess sunlight: turns exposed root tops green	Accumulated rain: carrots more vulnerable to diseases like blight during wet seasons
Irrigation	Week 2-3					
Selective herbicide	Week 4					
Fertilizer, and Pest & Disease Management	Week 5-6	Cymocanil - fungicide for late blight Chlorothalonil - fungicide for early and late blight Lambda cyhalothrin - insectide for aphids and beetles Foliar fertilizer - contains nitrogen, phosphate, etc				
Thinning and hilling up	Week 7 (by 60 days)	Labor requirement for thinning and hilling up: 10 people, 10 days, per ha	Unique to carrots Weeding is taken care of through hilling up, when weeds are covered with soil.			
Pesticide application	Week 9	Cymocanil - fungicide for late blight Chlorothalonil - fungicide for early and late blight Lambda cyhalothrin - insectide for aphids and beetles				
Harvest	Week 11					

Table 7. Crop climate calendar summary for potatoes.

Crop	Potatoes					
Cultivation practices	Timing	Inputs	Description	Priority Weather and Climate Risk		
Land preparation • Herbicide • Plowing • Farrowing • Chicken dung • Lime	10-15 days before planting 1 month before planting	 Chicken dung Lime				
Purchase of seed		1500 - 2000 kg/ha at the minimum, depending on size of tuber.	Igorota seeds are easier to purchase in December to January. Granola seeds are easier to purchase in March and April.			
Storage of tubers	2 months - Igorota variety 4 months - Granola variety					
Planting	10-15 days ahead of consistent rains			Accumulated rain: potatoes more vulnerable to diseases like blight during wet seasons	Frost will kill young potatoes	
Hilling up and weeding	Week 7		Weeding is taken care of through hilling up, when weeds are covered with soil.			
Fertilizer, and Pest & Disease Management	Week 9 thru 15	Cymocanil - fungicide for late blight Chlorothalonil - fungicide for early and late blight Lambda cyhalothrin - insectide for aphids and beetles Foliar fertilizer - contains nitrogen, phosphate, etc				
Harvest	Week 18		Granola variety can be harvested early at 2 months and Igorota at 3 months. It is not advisable to harvest early as potatoes will not reach their maximum weight and size, and one runs the risk of scratching the potatoes.			

Identified priority risks, and next steps

Ideally, after weather and climate risks are identified, stakeholders will identify their high priority risks to determine which climate-sensitive decisions to take into decision analysis. To do this, they are asked to consider the likelihood of the risk occurring (can be as instance of occurrence in the last five to ten years), and an estimate of the damage it causes. Alternatively, they may be able to rank the risks simply as high, medium and low.

In Benguet, the identification of high priority risks emerged in the course of the discussions with the farmers. For cabbages, they identified this as diamond back moth. Diamond back moth is more prevalent during warmer season, where farmers will aggressively spray crops with pesticides to control their rapid spread. For potatoes and carrots, the top identified risk was blight, and in the same way cabbages are sprayed for diamond back moth, so are carrots and potatoes to protect them from early and late blight. Incidentally, LGU and academe stakeholders have recently also been debating the reintroduction of biological pesticides such as diadegma to control diamond back moth, and the need to reduce calendar spraying of chemicals for all plants for health purposes.

Taking this to verbal decision analysis in the subsequent co-learning and co-development sessions would involve identifying the climate-sensitive decisions that stem from these risks. This is an interesting example as it seems that the decision would not be whether or not to spray the crop, as they will do so regardless of weather—here, it seems the decision is how often to spray the crop, which could be in line with the initiative of MAO to move away from calendar spraying and base the pest and fungi management schedule on the needs of the crop and the prevailing climactic state. The potential for using weather and climate information to improve

value for farmers through better labor and pesticide input management is also something that literature has shown to be possible on multiple counts. The next steps here would be to identify the difference in outcomes from calendar spraying and otherwise, and how these outcomes change vis-à-vis weather and climate states—and if possible, quantify them as well. This is where verbal decision analysis and subsequently RCDA will come into play.

1.14. Preliminary comments on the tool

The crop climate calendars were understandable to the farmers during the guided discussions, but will still be subject to revisions based on their helpful comments. Primarily, the farmers requested less words and more pictures to help them take the calendar in at a glance, making the next challenge to revise it as such without losing meaning or content in the process. It is possible that project partners ATI or other communications and training experts may be involved in the design of the calendar down the line to ensure this, and to make any other changes that facilitate learning and make the calendars more audience appropriate.

Overall, the crop climate calendars are decision making tools in the midst of development with farming stakeholders in Atok, Benguet. If executed properly, it may make it easier for AEWs and farmers alike to find cultivation practices not only documented in one place, but also presented under the lens of the weather and climate states that influence them. This may also the decision making process that allows for the better integration of weather and climate information and farming.

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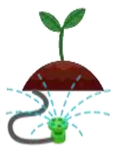
Clements, J., Ray, A. & Anderson, G. 2013. The value of climate services across economic and public sectors: A review of relevant literature. USAID. https://www.climatelinks.org/resources/value-climate-services-across-economic-and-public-sectors-review-relevant-literature (accessed on November 26, 2019)

Starke Aryes. 2014. Cabbage production guidelines. https://www.starkeayres.co.za/com_variety_docs/Cabbage-Production-Guideline-2014.pdf (accessed on November 26, 2019)

Appendix: Crop calendar diagrams

Crop Climate Calendar (Rainfed)

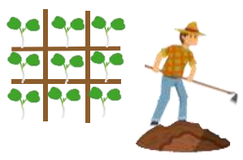
Crop	Carrots																		
Notes	More laborious, but significantly less risk of pests and diseases versus cabbage and potatoes.																		
Calendar Months				March				April					May				June		
Week				1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Stages of grow	**crop decision**	**crop variety**	**land preparation**	**planting**	**seed germination**		**growth of leaves**	**growth of roots**						**harvest**	**post-harvest washing**		**storage**		
																			
																		
farming activit	requires less inputs than cabbages and potatoes, but requires more labor.	•Terracotta variety is most popular in Atok •Usually requries 60 cansx100 g seeds for 1 ha*	**Land preparation** • Herbicide • Plowing • Farrowing • Chicken dung - 10-15 days before planting. • Lime - 1 month before planting.	Carrots can be planted closer together than other crops.	**irrigation**		**selective herbicide**	**Fertilizer, and Pest & Disease Managment** • Spray as needed for pests and diseases. • See notes for possible active ingredients	**thinning and hilling up by 60 days** need to do this well or carrot will not grow; more labor intensive here**		**pesticide application**							
remarks	*in highlands, carrots can be grown all year round*	*depends on the season*	*stony and heavy soil promote incidence of root defects*				*blight*	*•water is important during root development, soil should be soaked thoroughly* *•carrots grow slowly and cannot compete with weeds. Hence, weeding is important*											
weather and climate risks																			
accumulated rain				moonsoon rains will wash out seedlings				too much rain causes the carrots to rot, or form large, white "eyes" more rain brings more fungal diseases such as blight						early or delay harvest to save from monsoon					
temperature								higher temperature produces long slender roots with pale color best temp. range to grow carrots is 15.6-18.3 C											
soil temperature								carrots may fail to emerge and have lower quality if soil temperature is too high											
soil moisture								excessive moisture can result to poor quality											
typhoons														early or delay harvest to save from typhoon damage					
landslides	any landslides will cause the crop to be lost																		
floods															early or delay transportation, washing not recommended until it reaches market				
excess sunlight								root tops green when exposed to sunlight											
frost																			
onset of rainfall				carrots are directly seeded. Too much rain will wash away the seeds, On the other hand, seeds will not sprout in dry conditions and insufficient water.															

Chemicals	Brand	Description
Cymoxanil	Curezate	Fungicide for late blight
Chlorothalonil	Daconil	Fungicide that helps control early and late
Lambda cyhalothrin		Insecticide for aphids and beetles
Foliar fertilizer	Peter's	Contains nitrogen, phosphate, etc

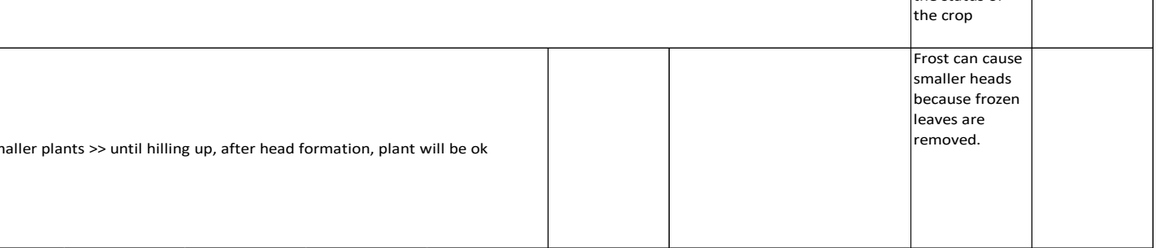
Footnotes

* Terracotta and other Japanese varieties: largest supply of seeds in Atok, higher % of germination, more resistant to diseases and pests, crop keeps for longer after harvest, good in any weather.
Chunhong variety: Korean; best low cost variety
Radish is also a good alternative: can survive the typhoon months, increased demand in market right now, can last in hotter weather; just needs better soil to be planted in
** Labor requirement for thinning and hilling up: 10 people, 10 days, per ha

Crop climate calendar (Rainfed)

Crop	**Cabbage**															
Notes																
Calendar month					March				April				May			June
Week					1	2	3	4	5	6	7	8	9	10	11	12	13
Stages of growth	crop decision	crop variety	seedbed preparation	land preparation	seed germination	cotyledon (seed leaves)	seedling (up to 5 true leaves)	6-8 true leaves	9-8 true leaves	precupping (approx 13-19 leaves)	cupping	early head formation	headfill	mature (approx 6-12' diameter head)		harvest	transport to market
																	
farming activity																	
farming activity			**Grow seedlings in seedbed**	**Land preparation** • Herbicide • Plowing • Farrowing • Chicken dung - 10-15 days	**Pest & Disease Managment** • Spray as needed for pests and diseases. • See notes for		**Transplant** 45-60 days after seedlings sprout.	**Transplant** 45-60 days after seedlings sprout.	**• Hilling up** **• Weeding**	**Irrigation (if possible):** •When colder: once a week • When warmer: twice a week (water		**Fertilizer application**	**Irrigation (if possible):** • Once every 2 weeks **Pesticide application:**	**• Thinning** **• Hilling up** **• Weeding******.**		
Pests, diseases			*club root*		***diamond back moth**, flea beetles, club root, leaf spot, and army worm.*	*flea beetles*	***diamond back moth**, flea beetles, cabbage maggot injury*		*the cabbage is a little vulnerable after hilling up and weeding*		*thrips*	*thrips, black rot*	*thrips, black rot*				*protect against foliage feeding insects*
Weather and climate risks																	
Water deficit	uneven watering throughout season results in stunted or cracked heads			Seedlings are aged around 60 days to make sure they are more resistant to drier conditions.			Cabbages will wilt. Solution: replant cabbage if there are extra seedlings; if not, plant other variety or other crop										
Accumulated rain	Total water req: approx 440mm too much rain washes out the nitrogen in the soil that the cabbage needs throughout its growth			Seedlings are aged around 60 days to make sure they are more resistant to the rains when they come.	requires approx 10-15 mm per week until week 6		Cabbage will rot. Solution: replant, stock an allowance of seeds, try to fix drainage to avoid this; but otherwise no hope to fix.				requires approx 25mm per week until harvest	cabbage head will not form		cabbage will rot	early harvest to save from monsoon rains	
Accumulated heat	Club root and other nematodes more prevalent when it's warmer, and more pests present during dry season. Will have to spray pesticides at closer intervals. **																
Excess sunlight															too much sunlight will cause severe wilting of the newly harvested heads		
Typhoons	at any stage, a typhoon will blow the crops around, so avoid planting during July-August typhoon season														early or delay harvest to avoid incoming typhoon, depending on the status of the crop		
Frost	Occurs in January and February, so avoid planting around November/December.***				Cabbages are vulnerable to frost in this stage.		Frost destroys smaller plants >> until hilling up, after head formation, plant will be ok								Frost can cause smaller heads because frozen leaves are removed.		
Temperature	Temperature primary consideration for choice of variety. Scorpio variety is most popular in Atok because it is most suited to cold temperatures. Rareball and Wonderball are planted in warmer, lowland areas. ****		For germination: Min: 4 deg C Optimum: 18 deg C Max: 35 deg C				For growth: Min: 4.5 deg C Optimum: 18 deg C Max: 24 deg C										
Onset of rainfall	After transplanting, seedlings need sufficient water in order to fully establish. Too much water will wash away the seedlings. On the other hand, insufficient water will damage the seedling and prevent it from growing.																
Hail									Farmers expect hail in April-May. Hail causes physical damage to crops.								

Chemicals	Brand	Description
Chlorypyrifos	Lorsban	For worms and beetles
Difenoconazole	Score	Fungicide (alternaria and ringspot)
Copper hydroxide	Kocide	Fungicide and bactericide (black
Foliar fertilizer	Peter's	Contains nitrogen, phosphate, etc
Green label biological insecticides		Diamond back moth
Spinetoram, Emamectin Benzoate	Radiant, Proclaim	Diamond back moth



Footnotes

[1] It is recommended that lime is added at least one month before planting. In practice, however, lime is added around the same time as chicken dung to reduce labor costs. This neutralizes soil acidity and controls nematodes that cause clubroot.

[2] It was observed in recent years that pests tend to attack traditional varieties more, but per the MAO farmers have not changed their pest management practices to reflect this.

[2] Cabbage is sprayed more in the dry season because pests are a bigger concern. Potatoes and carrots are sprayed more in the wet season because fungi and diseases are a bigger concern.

[3] The magnitude of the effect of frost depends on the stage of growth of the cabbage. If in the seedling stage, frost could reduce yields by >50%; if in the heading stage, this could be close to only 10-20%. The thickness of the frost is also a consideration.

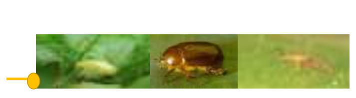
[4] While temperature is the primary consideration, the varieties also have other important characteristics. Scorpio is tastier, Wonderball is more resistant to diseases and bigger than Scorpio, and Rareball is more suited to wetter conditions and also bigger than Scorpio.

[5] Weeding is taken care of through hilling up, when weeds are covered with soil.

Crop Climate Calendar (Rainfed)

Crop	Potatoes											
Notes:	Can plant any time seeds are available, but tubers become larger in drier seasons.											
Calendar months					March	March	April		May / June	July		
Weeks						1 2 3	4 5 6	7 8	9 10 11 12 13 14 15	16 17	18	19
Growing stag	Farm Preparation	Selection of seed potato	Curing	Sprouting	Planting	Root Development	Vegetative growth	Tuber initiation	Tuber bulking	Maturity	Harvest	Storage
												
												
Farming activit	**Land preparation** • Herbicide • Plowing • Farrowing • Chicken dung - 10-15 days before planting. • Lime - 1 month before planting	**Purchase of seed potato**, 1500 - 2000 kg/ha at the minimum, depending on size of tuber.	**Storage of tubers** 2 months - Igorota variety 4 months - Granola variety		**Plant** 10-15 days ahead of consistent rains, so it rains on the crop	Can do preventive spraying, hilling up, fertilizer, and weeding, depending on farmers preference. Spray for tuber moths		**• Hilling up** **• Weeding** **•Fertilizer application**	**Fertilizer, and Pest & Disease Managment** • Spray as needed for pests and diseases. • See notes for possible active ingredients			can store up to 10 days
Pests, diseases						Blight, cutworms, tuber moths			Aphids, white fly, leaf miner, thrips			
Weather and climate risks												
Water deficit		Potato tubers grow bigger in the drier season. Granola variety preferred when drier.*		Delayed emergence	Potato tuber can last 1 month in the ground without rain. Past this, the potato might not sprout/ affects growth; in danger of tuber moth. This can be solved with irrigation, but there might be less production and longer cropping season.	Restricts root growth and uptake of nutrients Potato will wilt	Limited plant development Limited number of stolon	Limited foliage development Limited tuber development	Limited number of tubers Limited tuber size Distorted tubers	Limited tuber density Limited tuber size		
Accumulated rain		Igorota variety more resistant to late blight, so is preferred in the wetter season.*			15-20 days of heavy monsoon rains will cause the potato to rot. ****	Roots do not grow well Nitrogen fertilizer (to be applied 3-4 wks after planting) washes out Potato will rot	Erwinia decay from wet conditions		Too much water later in tuber growth season: lenticel development (bad), tuber splitting Root decay Tuber decay Farming activity: more rains, spray more		Choice to: Delay harvest date, but wet potatoes spoil easier; time harvest between gap in monsoon rains;	
Accumulated heat						Roots might not grow at temps beyond 35 degrees	Harder to grow leaves at temperature beyond 30 degrees Brings in more pests					Green/sprouted potatoes Rotten potatoes
Temperature					2 degrees C = lengthened cropping season; though temperatures rarely drop this low.	Optimal root development: bet 15-20 deg celsius	Optimal leaf development: 20-25 degrees celcius		More susceptible to low temperatures when tubers are present, and plant might not develop properly or die. This is a risk up to 2-2.5 months/maturity stage.			
Humidity/Moisture		Igorota moderately resistant to late blight					Warm and moist conditions: Early blight	Moist: late blight				Green/sprouted potatoes Rotten potatoes
Soil temperature								Optimum temp for tuber initiation is 15-20 deg celsius				
Soil moisture								Fluctuations in soil moisture: malformed tubers, growth crack Uneven soil moisture leads to scabs disease				
Excess sunlight								Tubers' exposure to sunlight results in green, poisonous tubers; hilling must be done sprouts emerge from the soil Consequences: reject potatoes; they taste bitter and have low prices; cannot feed to animals, but CAN make into planting materials				Lack of storage: exposure to sun, and risk of green potatoes
Typhoons											Delay harvest date	
Landslides	any landslide means the potatoes will be lost											
Floods	standing water will rot the potato plant at any stage											
Frost			Frost will kill potatoes < 2-3 months old; i.e. potatoes not at maturity stage				control any frost at this stage with sprinkler; more hilling up, but frost not usually a concern past April					
Foggy/cloudy/mahamog									more risks of diseases and pests			
Wind									Bad wind will break plant stems, leading to less tuber formation.			
Hail	more resilient to hail in earlier stages, when leaves and stems can recover from physical damage and support tuber growth later on.											

Chemicals	Brand	Description
Cymoxanil	Curezate	Fungicide for late blight
Chlorothalonil	Daconil	Fungicide that helps control early and
Lambda cyhalothrin		Insecticide for aphids and beetles
Foliar fertilizer	Peter's	Contains nitrogen, phosphate, etc



Footnotes
*Igorota seeds are easier to purchase in December to January. Granola seeds are easier to purchase in March and April.
** Weeding is taken care of through hilling up, when weeds are covered by new soil. Labor requirement for weeding: 10 people for 3 days for 1 haLabor requirement for hilling up/applying fertilizer: 10 people for 2-3 days for 1 ha
*** Labor estimates for harvest:10 people, 3 days, 1 ha
**** This is less of a concern for farmers with good drainage, and will harvest their produce depending on price. There are usually no potatoes in the July-August typhoon season.
***** Granola variety can be harvested early at 2 months and Igorota at 3 months. It is not advisable to harvest early as potatoes will not reach their maximum weight and size, and one runs the risk of scratching the potatoes.