

# CORN CROPS IN BUKIDNON, PHILIPPINES

## Synthesis from field survey and literature



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## LIST OF ACRONYMS

Abbreviation	Meaning
GIS	Geographic information system
OPV	Open pollinated variety – traditional corn variety
GMO	Genetically modified organism
C <sub>3</sub> photosynthesis	Photosynthesis pathway being the unique pathway which fixes CO <sub>2</sub>
C <sub>4</sub> photosynthesis	Photosynthesis pathway that spatially uncouples the CO <sub>2</sub> fixation
HYV	High yield variety (i.e. GMO and hybrid corn)
Bt corn	One trait GMO corn variety created from the use of <i>Bacillus thurigiensis</i>
RR corn	On trait GMO corn variety which is herbicide tolerant – Roundup Ready corn
DAP	Days after planting

## 1. BACKGROUND

This report was compiled in the framework of the ARES-LUCID project, an interdisciplinary and collaborative research including sociological, economical, GIS and remote sensing studies. It analyses socio-economic impacts and implications of land use change in Philippine uplands related to high-input commercial corn adoption. In the context of its geomatics component, this document compiles corn information collected from interviews, field observations and literature during the Julie Transon's mission in the Philippines, from the 9 January to the 6 February 2017, in the Bukidnon province (Figure 1). Photos that will be found in this report without references were taken during this mission.

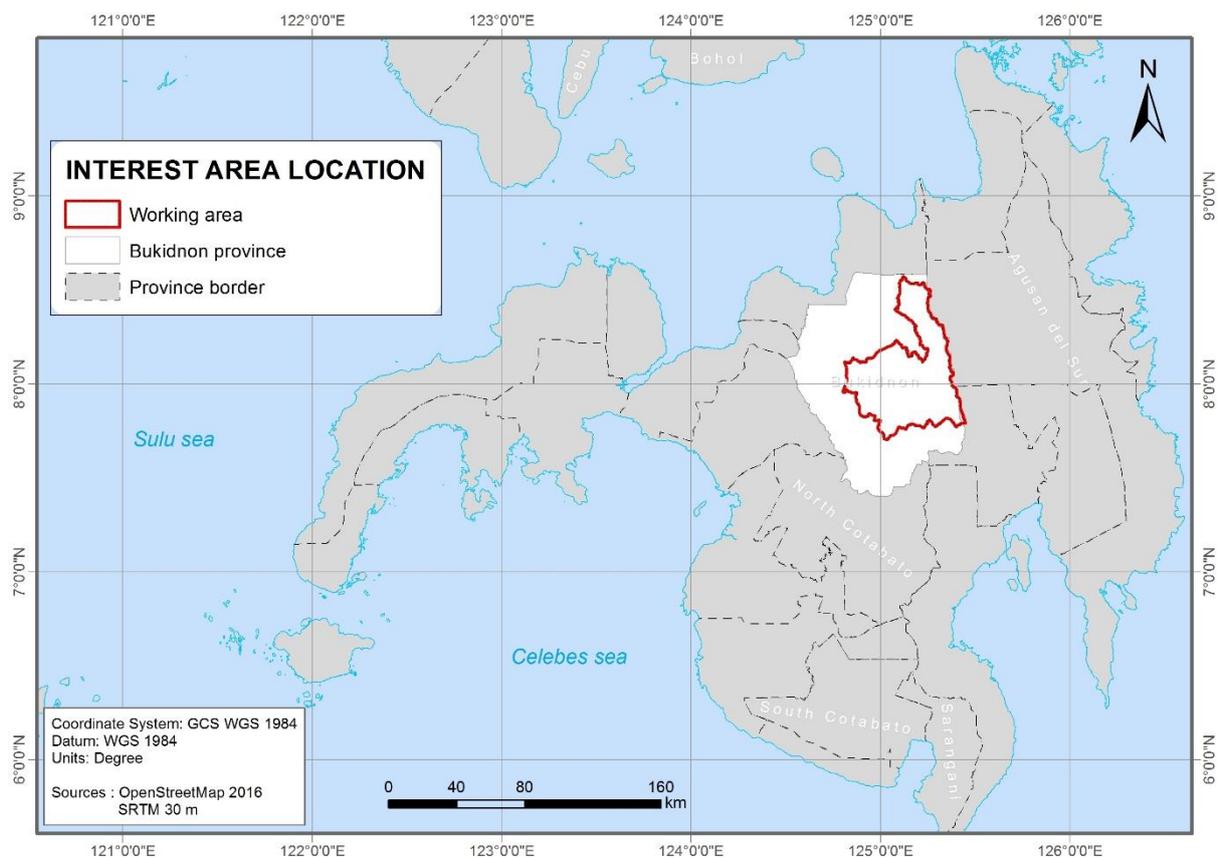


Figure 1 : Location of the LUCID study area of the Bukidnon province during the mission from the 9 January to the 6 February 2017, Mindanao island

### 1.1. SCOPE AND OBJECTIVES OF THE DOCUMENT

The objective of this report is to summarize the current situation of the corn crops for the ARES-LUCID stakeholders taking part in the March meeting in Bendum. A global description of the plant is therefore introduced before the focus on the corn crop situation.

Therefore, this document is describing the different characteristics of the maize plant such as its morphology, its physiology and its development stages and is reviewing the current situation of the Filipino corn crops through the presentation of their extent in the country's crop yield, their location, their agronomic practices and the corn lines cultivated.

## 1.2. ACKNOWLEDGEMENTS

A special thank you goes to Andres and Ching Ignacio, and Oliver and Lalayne Narreto who helped me to learn more about the crop system in Bukidnon and to meet people on the field. I also express a hearty thanks to Pedro, Toto, Gino, Mora and the others who helped me on their own way during my stay.

## 2. CORN CROPS

Corn or maize, also known as *Zea mays* L., is an annual herbaceous tropical plant (Tela Botanica, 2011). This plant species originally comes from Mexico but is currently planted all around the world as a forage and industrial crop (Paliwal, Granados, Lafitte, & Violic, 2002). It is one of the first cereal cultivated in the world, before rice and wheat thanks to its very high productivity. Corn crops can be classified in two main groups according to their latitude. Maize fields located between equator and 30° of latitude are considered as tropical corn crop and those located at higher latitudes are designated as tempered corn (OGTR, 2008). Tropical and tempered corn mean yield reach respectively 1 800 kg/ha and 7 000 kg/ha. Higher tempered corn yield is due to its longer vegetative cycle.

### 2.1. MORPHOLOGY

Maize is a slender plant reaching up to 3 meters high with opposing and alternate leaves along cylindrical stem (OGTR, 2008; Tela Botanica, 2011). This single erected stem is around 3 to 4 cm of thickness and is divided with nodes and internodes (Sapkota, 2012). One leaf is attached to each node and appears on the opposite side of the stem with respect to the previous one (Figure 2B). Leaves are composed of 3 distinct sections: a sheath surrounding the stem, the limb separated from the stem and the collar located between them (Figure 2A). Root system is composed of seminal roots, crown roots and aerial roots (OGTR, 2008).

Corn is a monoecious plant, which does mean that both male and female flowers coexist on the same individual (Bertin, 2015; OGTR, 2008). This plant is usually pollinated by wind or by gravity, given that male flowers are located above female organs (Bertin, 2015). In order to favour cross-fertilization while allowing also self-fertilization, anthesis occurs up to 15 days before the blooming of female flowers (OGTR, 2008). Anthers are located on a terminal branched tassel at the top of the plant (Figure 3A). Female flowers are located into a long axillary organ called ear on which grow silks and stylar canals of ovaries (Figure 3B). Silk appearance on the ears corresponds to a high sensitivity to stresses and diseases for the plant (Jamago, 2017; OGTR, 2008). In the Philippines, corn can grow up to two ears on the same plant if the soil possesses good nutritional qualities (Jamago, 2017).

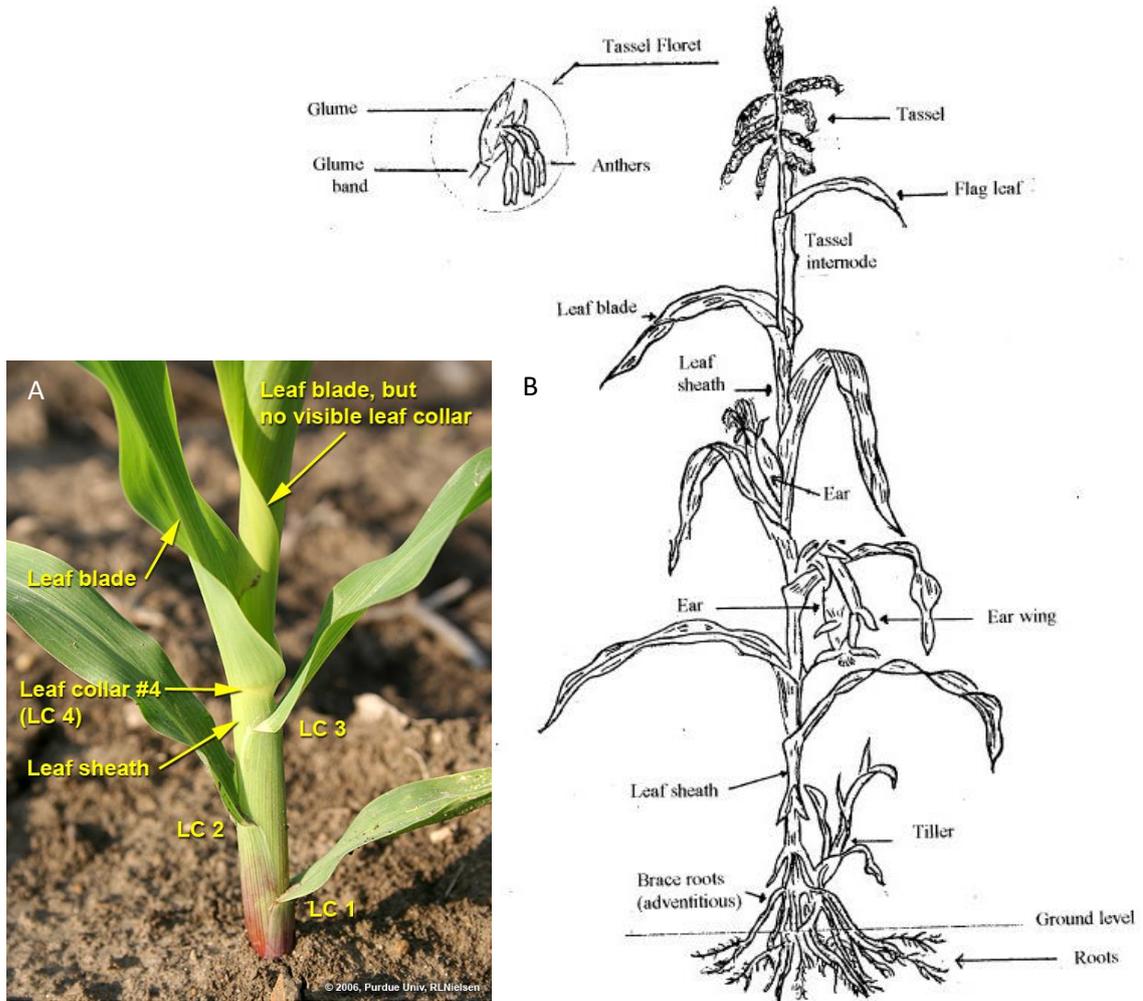


Figure 2 : Parts of corn leaf (A) and corn plant diagram (B) (Nielsen, 2014; SWI, 2015)



Figure 3 : Male flowers located on the tassel (A) and female inflorescence with young silks (B) (Spedona 2007)

## 2.2. PHYSIOLOGY

### ▪ Temperature

As a tropical plant, corn is sensitive to temperatures lower than 10°C and above 40°C (Bertin, 2015; OGTR, 2008). Passing these temperature levels, corn development can be affected. Optimal growing temperature depends on maize cultivars. For example, tropical highland cultivars can better develop at lower temperatures than lowland or middle-land cultivars (OGTR, 2008).

### ▪ Photosynthesis

Corn is one of the most productive crops in the world due to its specific photosynthesis process, like others tropical plants, designated as  $C_4$  plants (Bertin, 2015; OGTR, 2008; Paliwal et al., 2002). These plants spatially uncouple photosynthesis reactions in two separate kinds of cells (mesophyll cell and bundle sheath cell) to use carbon dioxide more efficiently than  $C_3$  plants. Unlike  $C_3$  plants,  $C_4$  plants photosynthetic yield is independent from temperature that usually negatively affects the production of sugars (Figure 4).

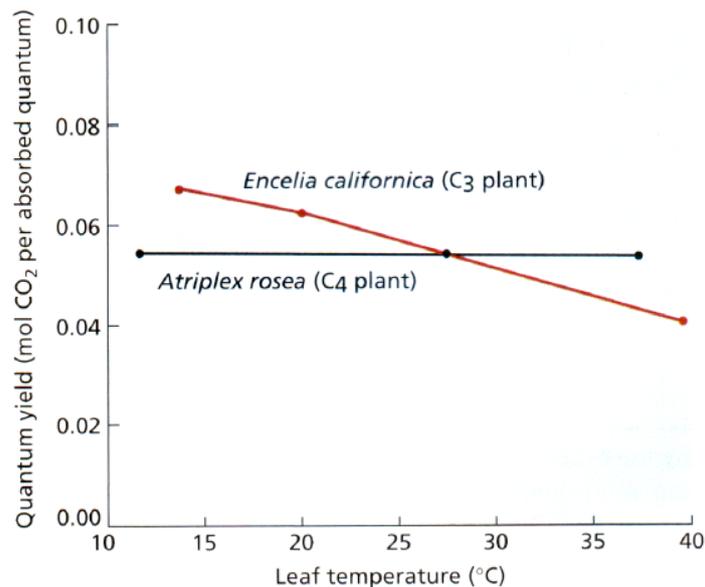


Figure 4 : Evolution of quantum yield of photosynthesis of  $C_3$  and  $C_4$  plants (Bertin, 2015)

### ▪ Water

Water accessibility is a limiting factor of corn productivity, particularly during the flowering stage (OGTR, 2008). During this period, every day of water stress during this period affects grain yields up to 8%. But water deficiency is not the only water stress that can affect corn development. Waterlogging damages roots due to anaerobic respiration can lead to development problems (OGTR, 2008).

### ▪ Nutrients

High availability of nitrogen (N), phosphorus (P) and potassium (K) is required by corn plants to grow (OGTR, 2008). In optimal conditions, availability of nitrogen limits corn development and its lack affects leaf production, flower appearance and ear growth of corn crops (OGTR, 2008). Leaf area index, and

thus biomass, is mainly provoked by a lack of phosphorous availability, such as potassium deficiency (OGTR, 2008).

### 2.3. DEVELOPMENT STAGES

Corn development is usually declined into various stages and is characterized by two main phases: the vegetative and the reproductive phases (OGTR, 2008; Pioneer, 2017; Roozeboom & Sindelar, 2015). In this report, we chose to group some of them into 6 distinct classes in order to be closer from our field work identification (Figure 6).

#### ▪ STAGE 1 – Germination and emergence

Corn emergence begins once the coleoptile (i.e. the first leaf of a monocotyledon plant) appears out of the soil surface (Pioneer, 2017). This phase lasts around 3 to 5 days and depends on temperature, accessibility to water and depth of the seeds (Bertin, 2015; Paliwal et al., 2002). The high dimension of corn grains enables this quick growth rate. Coleorhiza and radicle are then emerging and are followed by seminal roots which play a temporary root system role until the appearance of 3 leaves (Figure 5) (OGTR, 2008). During this stage, leaves are not fully developed yet, i.e. no leaf collar is fully visible (Roozeboom & Sindelar, 2015).

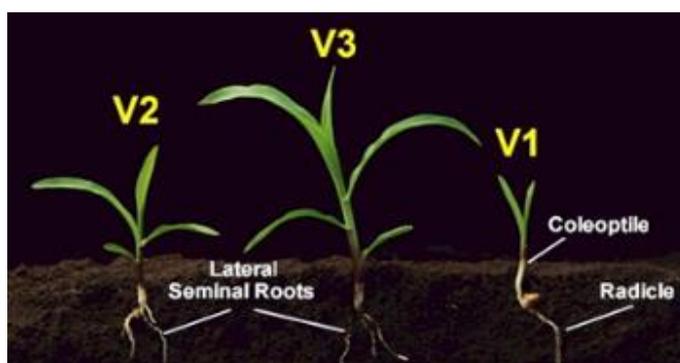


Figure 5 : Corn seedlings at the first growth stages (agKnowledge Spotlight, 2016)

#### ▪ STAGE 2 – Early vegetative

The early vegetative stage is characterized by the appearance of secondary roots on nodes below the soil surface and by the full development of leaves (OGTR, 2008; Roozeboom & Sindelar, 2015). However, some of them may emerge from the soil and are then called brace roots (Figure 2B). The vegetative stage has a determined development, which does mean that the number of leaves is fixed (Bertin, 2015). Once 5 leaves are emerged, the tassel begins its differentiation and at the end of the stage, senescence may already begin on the first leaves (OGTR, 2008).

#### ▪ STAGE 3 – Late vegetative

During the late vegetative stage, roots and leaves are both growing rapidly and internodes are elongating (OGTR, 2008). By the end of this stage, tassel reaches its final size but has not emerged yet and ear shoots are appearing (Roozeboom & Sindelar, 2015). The plant is close to reach its final high (Pioneer, 2017). Senescence begins on the first leaves that are not able to photosynthesize anymore.

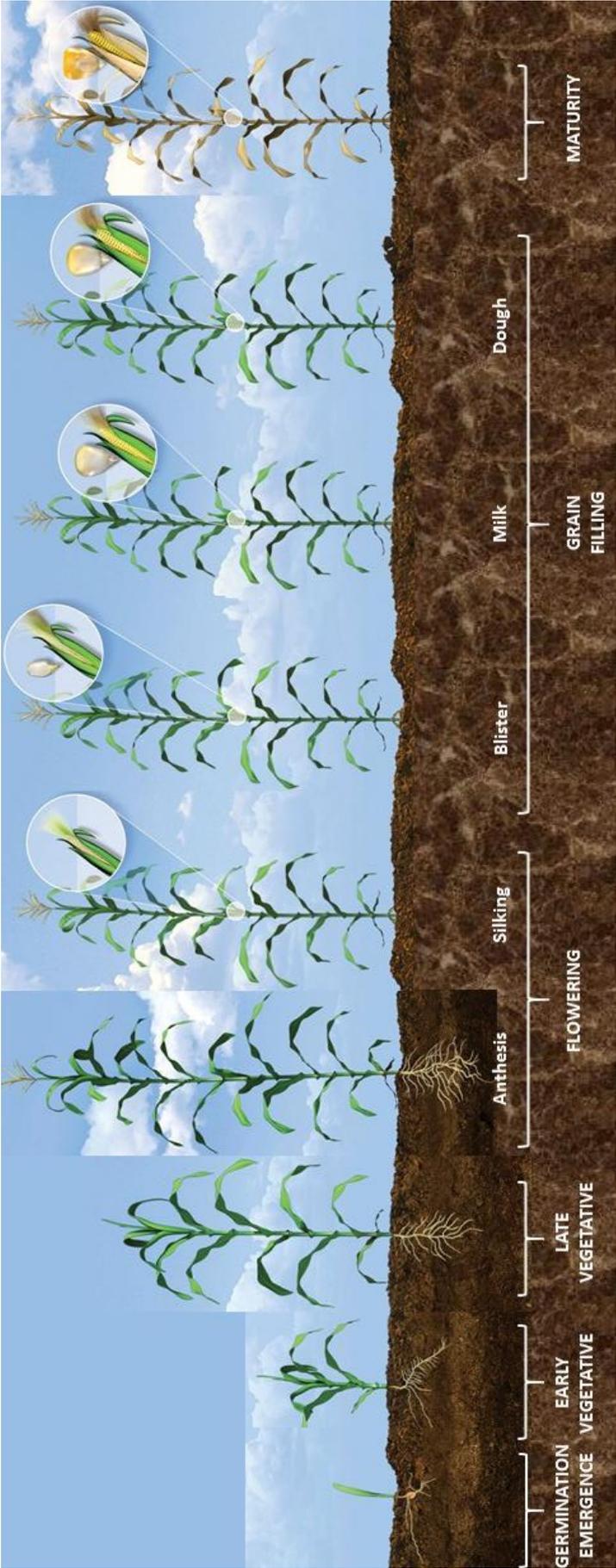


Figure 6 : Corn crop development stages (from Pioneer, 2017)

#### ▪ STAGE 4 – Flowering

Flowering stage corresponds to anthesis and silking. Pollen is produced on the tassel up to 15 days before the silking (OGTR, 2008). Pollination occurs once silks catch falling pollen grains that take around 24 hours to reach the ovule (Pioneer, 2017). Two to 3 days are required to pollinate all silks of an ear. Maize plant is the most sensitive to environmental stresses at this stage (Jamago, 2017; OGTR, 2008).

#### ▪ STAGE 5 – Grain filling

When pollination is achieved, the grain filling stage begins. Kernels will then pass through 4 phases: blister, milk, dough and dent phases (Figure 7) (Pioneer, 2017). During the blister phase, kernels are white and silks become darker and dry. Kernels reach an 85 % moisture which will gradually decline from this phase to the maturity phase (Roozeboom & Sindelar, 2015). Yellow kernels indicate that corn entered into the milk phase; when the embryo grows rapidly and kernels accumulate dry matter (Bertin, 2015). Silks are then completely brown and dry and kernels have an 80 % moisture. At this moment, cell expansion and starch accumulation are the main causes of kernel growth (OGTR, 2008). The dough phase is characterized by kernels of 70 % moisture (inner kernel fluid gets a pasty consistency) and a rapid growth of the embryo (Pioneer, 2017). The ear gets a brighter yellow colour (Bertin, 2015). Finally, during the dent phase, kernels reach a 55 % of moisture content and a starch line is appearing in the kernel (Pioneer, 2017).



Figure 7 : Reproductive growth stages (Pioneer, 2016)

#### ▪ STAGE 6 – Maturity

During the maturity stage, kernel moisture reaches 30 to 35 % (kernels are drying from the top to the bottom of the ear) and kernels are completely dented (Pioneer, 2017). Kernel growth is then ending (dry matter accumulation is over) and the plant is no longer green.

## 2. CORN IN THE PHILIPPINES

### 2.1. GENERAL STATISTICS

After rice, corn is the second most productive crop of the Philippines, reaching 7 770 metric tons on 2.61 million hectares in 2014 after a nearly constant increasing productivity since 2003 (Figure 8A) (Bureau of Agricultural Statistics, 2008, 2011; Gerpacio, Labios, Labios, & Diangkinay, 2004; Philippine

Statistics Authority, 2015). Such a productivity increase was also observed in the Bukidnon province which was the second most productive province in 2014, after Isabela (Figure 8B), generating respectively more than 10 and 15 % of the total production of the country. The major part of this increasing corn production is dedicated to cattle or poultry feeding (around 60 %) while 40 % are used for a domestic consumption (Bureau of Agricultural Research, 2011). Nonetheless, it is worth mentioning that the results of Philippine Statistics Authority still have to be validated.

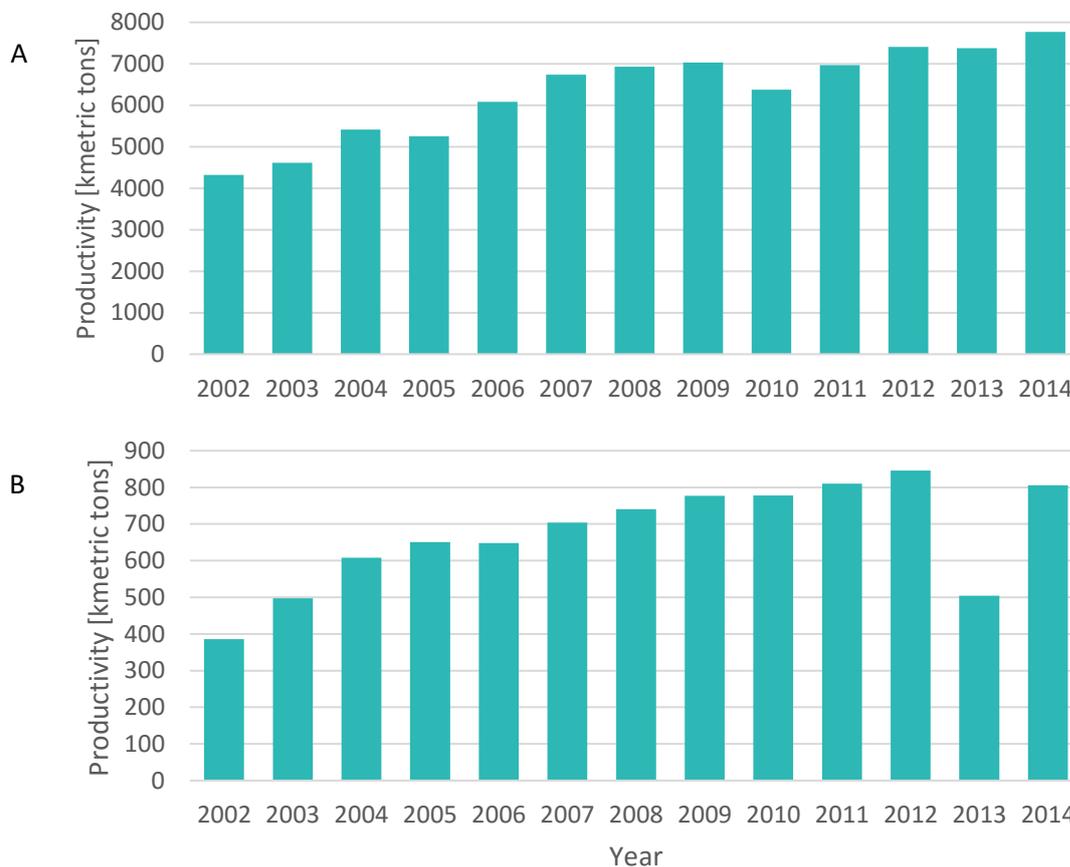


Figure 8 : Corn production between 2002 and 2014 (A) in the Philippines and (B) in Bukidnon (Bureau of Agricultural Statistics, 2008, 2011; Philippine Statistics Authority, 2015)

However, despite this increase of productivity, Philippines corn production is still low and inefficient compared to other major corn-producing countries like Thailand or United States (Bureau of Agricultural Research, 2011). Climate change (typhoons, droughts, etc.), insect pests (corn borer, corn plant hopper) or diseases (corn rust, corn downy mildew, corn leaf spot, etc.) are such origins of corn production damages. The rusticity of Philippine corn sector takes also a part in this difference of productivity because of a lack of adoption of new technologies, high harvest losses and inadequate transport infrastructure (Bureau of Agricultural Research, 2011; Lanthier, 2013).

## 2.2. CORN AGRO-ECOLOGICAL AREAS OF THE PHILIPPINES

Three agro-ecological areas can be identified for corn production in the Philippines, based on the elevation of the landscape: uplands, lowlands and middle-lands (Gerpacio et al., 2004). Upland areas, where corn is mainly grown, refer to a hilly and rolling topography (Gerpacio et al., 2004). Upland slopes are steeper than 15 % and corn productivity reaches a top between July and September thanks

to 2 to 3 crop cycles per year. Some upland farmers still grow the traditional corn, the open-pollinated variety (OPV), which is mainly cultivated for home consumption. Therefore, OPV crops are planted on very limited field surfaces in the uplands.

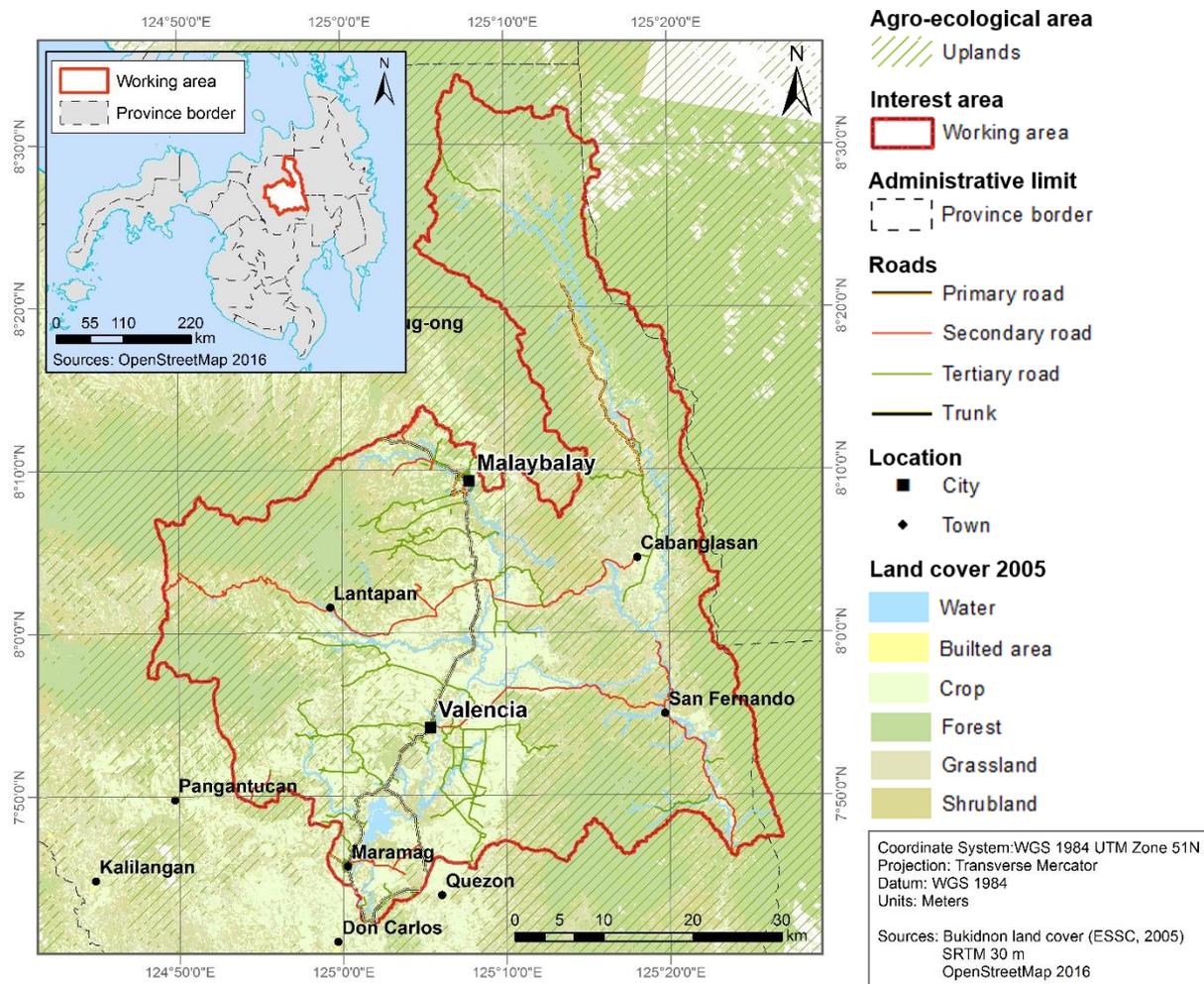


Figure 9 : Location of the upland's ecological zones in the LUCID study area of Bukidnon province

Middle-lands refer to areas with a majority of 16 to 32 % slope (Gerpacio et al., 2004). Landslides represent thus a problem due to the natural topography. Moreover, corn is mainly planted on these hilly areas, which exacerbate even more the landslide problem because of the high proportion of exposed soil.

Lowland corresponds to slightly sloped areas which are usually flooded during rainy periods (Gerpacio et al., 2004). In these zones, corn crops used to be rotated with rice fields depending on the season of the year (Jamago, 2017). Rice was then used to be planted during the rainy season, and corn which is a less water deficiency sensitive crop, was grown during the dry season. But now that GMOs are introduced and well established in the country, rice fields are mainly growth all year long in the bottom of valleys and corn crops are mainly taking place on the slopes.

### 2.3. CORN MANAGEMENT PRACTICES

Most of the corn crop operations are realized by human or animal power and very few farmers can afford the mechanization of their practices (Gerpacio et al., 2004). If mechanization is afforded, tractors are used only but for spraying processes because of the low cost labour force in the country (Jamago, 2017). Land preparation usually consists in 3 operations. Plowing is realized just after the harvest of the previous crop and prevents weed growth and incorporates organic matter into the soil. The second operation consists in harrowing the field to level it and to limit clods. This operation is then followed by furrowing just before planting the next corn cycle. For GM and hybrid varieties, corn is planted at a density of 20 cm by 70 cm. Once harvested, corn ears are sun-dried and then selected for the next planting or sold.

Now that GMOs are commonly planted in the country, crop calendar is no longer as stable as before. Indeed, this variety is much more flexible than the previous ones and allows the farmer to harvest up to three cycles a year if the first one is planted early enough (Jamago, 2017). The first crop cycle is seeded between March and April and is harvested around August. The second cropping is then seeded in September and harvested in November while the third one is seeded between December and January and is harvested in March or April. However, even GM corn has to take the weather into account. Seeding can't happen during the rainy season, in June (Jamago, 2017). Therefore, this third cycle is a highly risky crop because of a potential early rainy season that could happen during the flowering stage, the most sensitive corn stage.

Table 1 : Corn crop calendar in the Bukidnon province expressed in days after planting (DAP) (Jamago, 2017; Narreto, 2016)

DAP	STAGES / PROCESS
<b>1</b>	Seeding
<b>5</b>	Leaves appearance
<b>10</b>	3 leaves – 1 <sup>st</sup> application of fertilizer
<b>15</b>	Spray for weeds
<b>35 – 40</b>	Last application of fertilizer – Closing of operations – Maximum biomass
<b>40 – 60</b>	Flowering
<b>90</b>	Beginning of leaves browning
<b>110 – 120</b>	Harvest

### 2.4. CORN LINES IN THE PHILIPPINES

Yellow corn and white corn are the two main types of maize that are cultivated in the Philippines (Lanthier, 2013). The white corn variety mainly corresponds to the open pollinated variety (OPV) corn and yellow corn is represented by hybrid and GMO varieties (Gerpacio et al., 2004). Each of them is used for different purpose. Moreover, GMO and hybrid corn are also designated as high yield variety (HYV) corns.

- **Open pollinated variety**

Open pollinated variety (OPV) is the traditional white corn variety providing seeds which can be reused for every next planting cycle (Ocampo et al., 2013). Thanks to this characteristic, this variety has been adapted many times to the different Philippine environments. In 2014, white corn constituted less than a third of the total production of the country (Philippine Statistics Authority, 2015). This traditional variety was mainly used for home consumption as a carbohydrate substitute for rice in periods of shortage in Mindanao (Gerpacio et al., 2004; Lanthier, 2013; Ocampo et al., 2013). It also provides interesting nutrients and requires few inputs but also low production costs. OPV corn is more easily digested, contains more proteins, fibres, minerals and antioxidants than rice (Ocampo et al., 2013). Moreover, OPV growth is asynchronous which avoid harvesting the all field at once and storing the entire production. The consumption can then being spread during a long period (Baldo, 2017).

- **Hybrid line**

Hybrid variety has been introduced in the Philippines in the 1980's and is mostly growth by farmers as cash income crop and as cattle feed because of its better yields when using the proper amount of inputs (Gerpacio et al., 2004; Lanthier, 2013; Ocampo et al., 2013). Moreover, this high yield variety uses to have a better resistance to pests, diseases and other stresses, but also seems to have a low germination. However, their seed cost is more expensive than OPV's (hybrid seeds have to be bought every new cropping season) and require more inputs. Since its implementation, hybrid corn areas have spread all over the country, replacing other crops such as OPV corn, sugarcane and vegetables (Gerpacio et al., 2004).

- **GMO line**

Genetically modified (GM) corn is another type of high yield corn variety that has been commercialized in the Philippines from 2002 and reaches now more than a third of the total corn produced in the country (Luces, 2014; Ocampo et al., 2013). This corn gradually replaced the hybrid and the OPV lines on the market, and is currently widespread in the country (Jamago, 2017). Indeed, good quality seeds of hybrid corn are not sold anymore and since a few years, the availability of OPVs became lower and lower (Jamago, 2017). Many companies provide farmers in GM corn seeds such as Pioneer, Monsanto or Syngenta but Pioneer is currently the main corn seller.

The main advantage of GM corn is its resistance to pests but this line requires fertilizer and is sensitive to bad weather conditions (Ocampo et al., 2013). Moreover, GM seeds of second generation are fertile but produce low yields, forcing farmers to buy new seeds for each crop cycle (Jamago, 2017). Two single traits of GM corn were introduced in Philippines at first: insect resistant varieties using *Bacillus thuringiensis* (Bt corn) and herbicide tolerant varieties called Roundup Ready (RR corn) (Luces, 2014; Ocampo et al., 2013). But currently, the major GM cultivated corn is a combination of five different traits, each one targeting a specific pest (Jamago, 2017). This 5 pest resistant GMO is called a stacked trait GM corn (Ocampo et al., 2013). To avoid pest mutation due to omnipresence of highly resistant corn crops, government restricted to 90 % the number of GM plants into the same field with a minimum of 10 % so called "hybrid" corn, which corresponds in fact to a single trait GMO variety (Bt corn).

GM corn varieties are mainly producing yellow grains (Ocampo et al., 2013). However, Mindanao farmers have been interbreeding Bt and RR varieties with hybrid and OPVs, creating a cheap and new

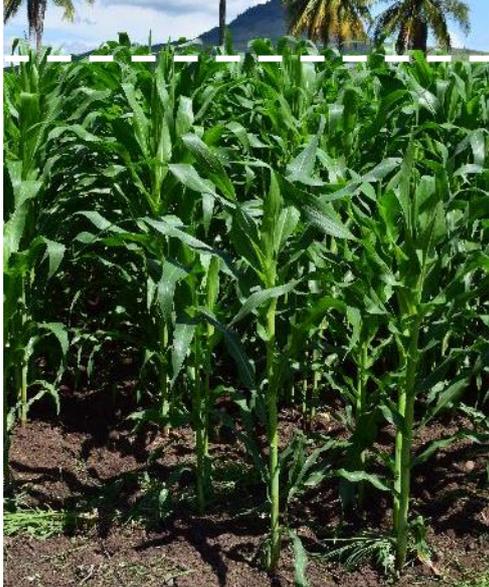
white corn variety (Mora, 2016; Philippine Statistics Authority, 2014). This so called *sigue-sigue* variety is resistant to Roundup herbicide and its seeds can be reused for successive crop cycles (Capistrano, 2015; Jamago, 2017; Mora, 2016). However, it generates lower yields than other GM corn varieties (Goulson, Hanley, Darvill, & Ellis, 2006). *sigue-sigue* seeds are easily obtained through cross-pollination between GM corn and traditional variety or hybrid variety (Masipag, 2015; Mora, 2016). This white variety and other GMO varieties also replaced little by little OPV corn for the household consumption.

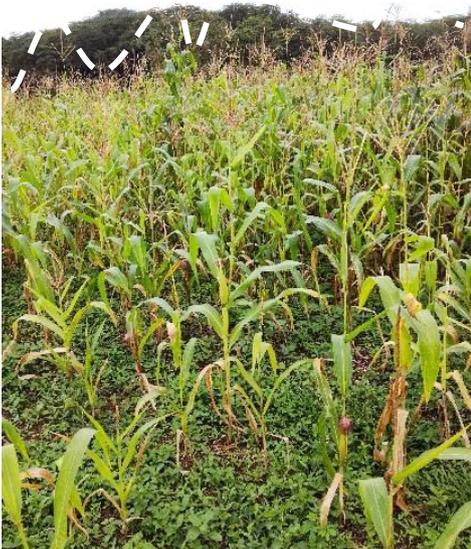
- **Corn lines comparison**

Distinguishing corn lines based on morphological characteristics represents a real challenge, even for corn experts (Baldo, 2017). Indeed, because the only difference between hybrid and GMO corn is one single gene, distinguishing these two lines only but thanks to morphological characteristics is impossible. However, differentiating OPV from HYV is easier, mainly during the flowering, grain filling and maturity stages (. Unlike HYV corn, OPV has an asynchronous growing. Therefore, OPV flowers and ears are appearing at different period into the same field. OPV plants are also reaching the maturity stage on different days.

Table 2 : Characteristics allowing the differentiation of the OPV, hybrid and GMO corn lines at each development stage based on the observations of the LUCID mission between the 9 January and the 7 February 2017

	OPV CORN	HYBRID / GMO CORN
Density	<p>Lower density</p> 	<p>Higher density</p> 

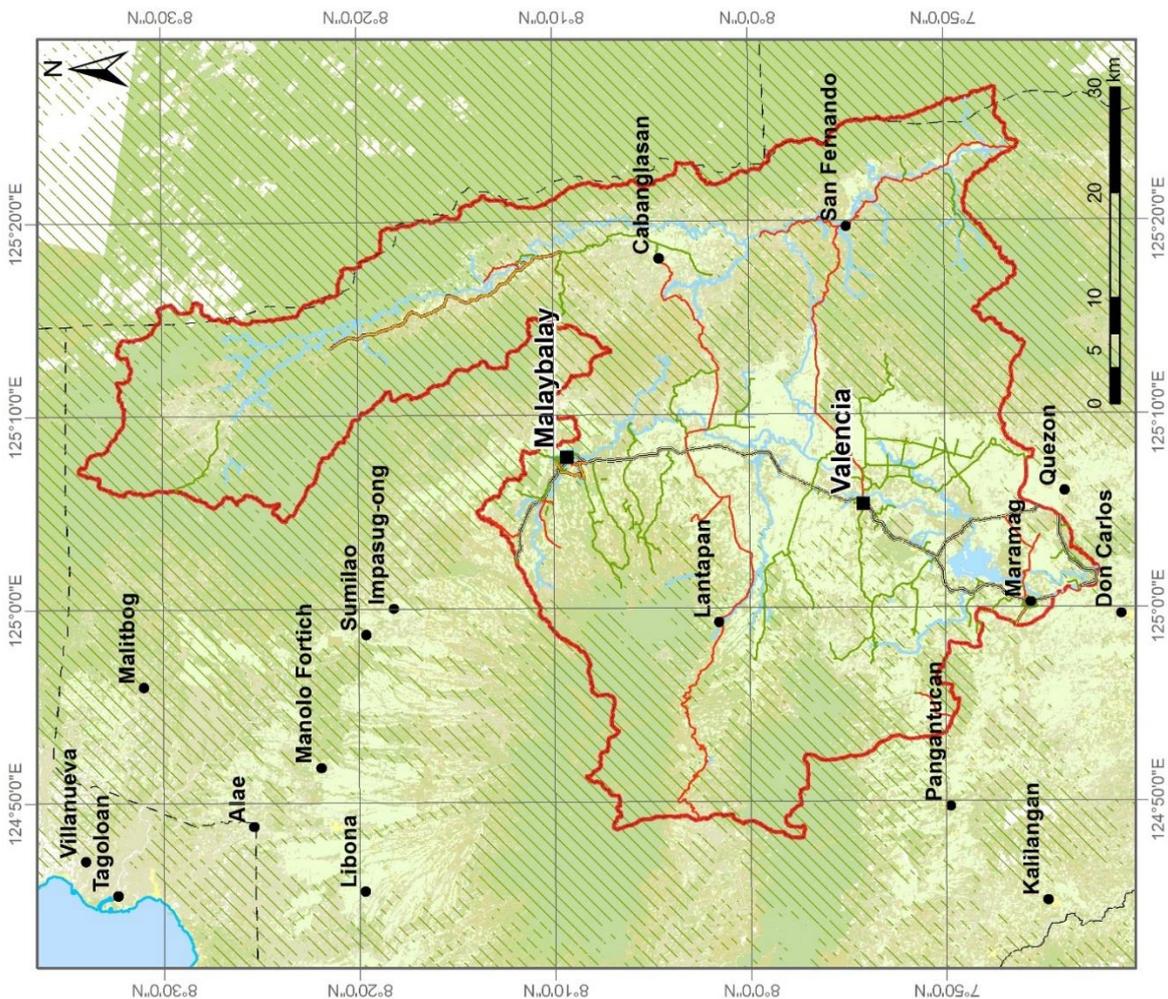
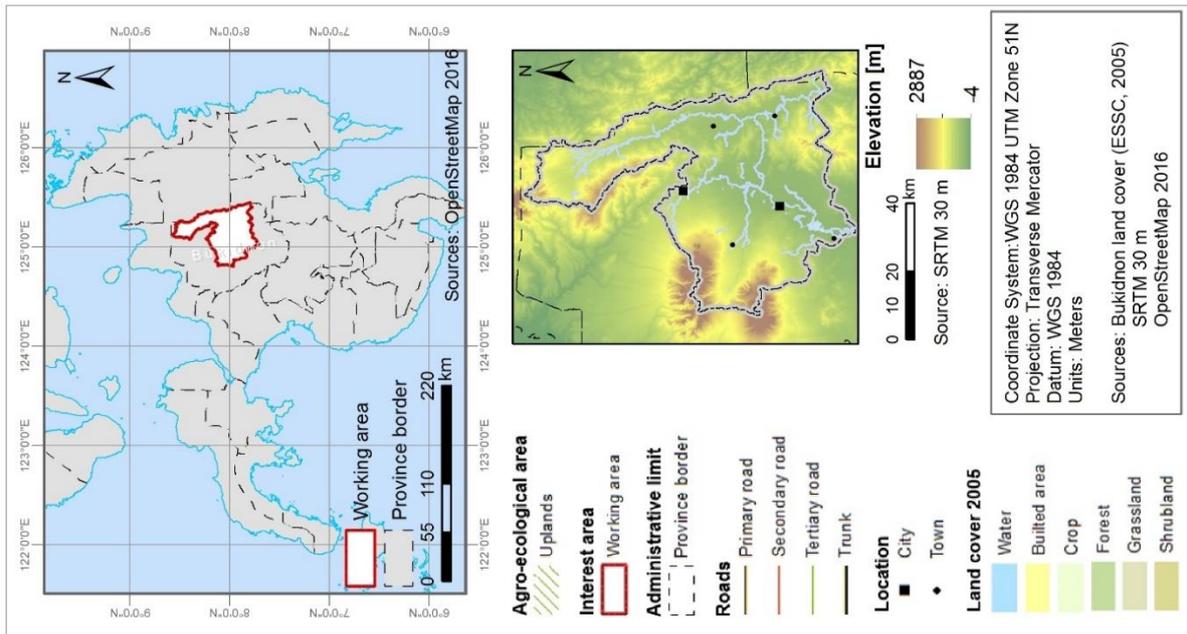
	OPV CORN	HYBRID / GMO CORN
Leaves	<p>Horizontal</p> 	<p>Vertical</p> 
Growth	<p>Early vegetative stage</p> <p>Similar</p> 	
Growth	<p>Advanced vegetative stage</p> <p>Non uniform but not so obvious</p> 	<p>Uniform</p> 

	OPV CORN	HYBRID / GMO CORN
Reproductive stage		
Growth	<p>Heterogeneous (more obvious than during the advanced vegetative stage)</p> 	<p>Homogeneous</p> 
Flowers appearance	<p>Asynchronous</p> 	<p>Simultaneous</p> 

		OPV CORN	HYBRID / GMO CORN
		Maturity stage	
Drying appearance	Asynchronous		
	Simultaneous		

### 3. ANNEXES

Annexe 1 : Location of the upland's agro-ecological zone in the LUCID study area of the Bukidnon province according to the elevation



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