Guidelines for Production and Irrigation Management of Selected Upland Crops

Abraham A. Caoili[1]

Introduction

Crop diversification has been a rudimentary practice among farmers in the Philippines, especially in relatively dry regions where rainfall is the main source of water for crop production. In some cases, farmers devise simple irrigation systems. They build temporary brush dams to divert part of the streamflow from nearby rivers or drainage channels.

Crop diversification is popular among farmers in the dry regions of northern Luzon, in the provinces of Nueva Ecija, Nueva Viscaya, Batangas, Cavite, arid in a few areas in the Visayas and Mindanao. Majority of them are subsistent farmers who cultivate small patches of lands. They informally learned diversified cropping through trial and error in an effort to produce more to sustain their food requirements. However, crop diversification has not been documented until recently.

'This paper discusses "Guidelines for production and irrigation management of selected upland crops", a project of the International Irrigation Management Institute (IIMI). Corn, mungbean, garlic and onions which are the major diversified crops grown in the Ilocos Region and Nueva Ecija are discussed. IIMI has targeted these crops in its applied research on crop diversification in irrigated areas with deficient water supply during the dry season.

Concept and agro-climatic setting for crop diversification

Irrigated areas which experience deficient water supply during the dry season are potential areas for crop diversification because of: (I) the need to maximize production by proper utilization of the available irrigation water during the dry season; (2) the chances of enticing active cooperation among farmers are greater than in strictly rainfed areas; **(3)** the opportunity to pilot-test and demonstrate innovative technology packages on crop diversification is more promising since the situation allows for a wider latitude for planning in terms of time and space and; **(4)** the general program of the government to concentrate countryside development in areas with existing infrastructure. The move to irrigate non-rice crops is a step toward institutionalizing the adoption of crop diversification technology. Relevant information on crop diversification is expected to be generated from research, pilot-testing and demonstration activities.

The Role of Water in Diversified Crop Production

Knowledge of soil-plant-water relationship is important in crop production, specifically in crop diversification. 'The study of soil-water relationship in crop production has given birth to what **is** now commonly known as ***water management*** or ***irrigation management***. Water management **is** defined as the judicious and rational application of irrigation water in order to promote an optimum environment for plant growth and development.

Because of increasing scarcity and expensive use of water, it is important to practice water saving methods and irrigation schemes. Water conservation makes possible larger areas to be served or the extension of cropping periods during the dry season. On the other hand, improper irrigation results in wastage of water and loss of soil nutrients by leaching, resulting to impaired land productivity and decline in crop yields.

Associate Professor, College of Engineering and Agro-Industrial Technology, University of the Philippines at Los Baños, College, Laguna.

In crop production water is used in many ways: (I) it keeps the soil in good tilth for efficient tillage operations; **(2)** it facilitates plant root penetration; **(3)** it dissolves soil nutrients for efficient absorption by the plant; and **(4)** it regulates soil temperature and maintains an efficient exchange of gasses between the atmosphere and the root zone.

Land preparation in dry agriculture using tillage equipment is possible only if soil moisture **is** slightly below field capacity. Therefore, farmers have to schedule the last or terminal irrigation.

Terminal irrigation should be applied when the standing crop **is** about **to** be harvested; the level of residual soil moisture will then be ideal for immediate plowing and harrowing in preparation for the next crop. Unnecessary and costly delays in planting will also be avoided.

If terminal irrigation is applied too late, the soil may still be wet for land preparation and hence, a drying period will be required. Each day spent to dry the field is time lost. Water which evaporated while drying the land is **also** considered a waste. If applied too early on the other hand, the soil may most likely undergo excessive drying before the scheduled harvest. Under such a case, the standing crop might dry up prematurely and adversely affect the quantity and quality of the produce. Moreover, substantial amount of water might be needed to replenish part of the evaporated soil moisture to a level that is optimum for tillage operations.

By maintaining enough water at the rootzone, the plants can develop healthy and vigorous roots whichcanpenetratedeeperand widerinto the soil. Soil which can enhance root development is an important consideration in crop production especially in dry areas where groundwater source proximate to the active rootzone exists. In such a case, crops have greater chances to succeed even if irrigation water is limited at the end of the cropping season.

Water facilitates absorption of soil nutrients. Soil nutrients in the form of soil solute are needed to sustain turgidity and photosynthesis for plant growth. Ideally, the level of soil water must be maintained at the upper 50% of the capillary range. This enables the roots to provide the water demand rate of the crops. During hot and windy days, plants exhibit temporary wilting due to high evapotranspiration. Farmers should then monitor the soil moisture level regularly ***so*** that the soil does not become excessively ***dry*** before the next irrigation is applied.

Water has a larger capacity to transmit and store heat than soil. Taken separately, a volume of water will neither warm up **as** rapidly nor attain **as** high a temperature **as** an equal volume of dry soil. When taken together, water plays the important role of regulating soil temperature. When the soil gets too dry, absorption of water and nutrients by the roots become increasingly difficult and the advective heat emitted from the dry soil surface causes plants to wilt resulting in **loss** of turgidity, stunted growth and reduced yields.

Soil Moisture Constants

In developing alternative irrigation management strategies vis-a-vis crop diversification, planners should understand the nature of **soil** moisture storage.

The soil's capability to store water depends on the texture and aggregate structure of soil particles. About 40-60% of the pore space between the soil solids can hold water while the remaining pores are **for** aeration and drainage of excess water. This proportion of air-water in the **soil fits** well with the requirements of most upland crops. When upland crops are grown with lowland rice under a crop diversification scheme the upland crops should be planted in welldrained soil.

In planning the alternative irrigation management strategies, planners should be familiar with the following:

Saturation is a condition where all pore spaces between **soil** particles below the **soil** surface are filled with water. A small volume of air **is** contained in saturated soils, which can be immediately depleted by **soil** microorganisms. Saturated soils are suitable only for lowland rice.

Field capacity **is** the amount of water or soil moisture retained after draining saturated soil. Each soil particle is completely surrounded by a relatively thick film of water. However, soil water are in the form of wedges between soil particles. It is through these wedges that plants absorb water.

Moisture is held in the soil against the pull of gravity. **Thus,** plants expend some energy (suction energy) to enable them to extract the soil water. At field capacity, the energy required is about one-third atmosphere (an equivalent tension force needed to raise a column of water to a height of 300 cm) in clay soil and about one-tenth atmosphere in sandy soil.

However, the energy needed to extract water from the soil increases rapidly than the corresponding decrease in soil moisture. The roots must satisfy such energy expense but only to a certain limit. Beyond such limit, the residual moisture is tightly attached to the soil particles and the corresponding energy needed for its extraction is beyond the normal absorptive capabilities of the plants.

Permanent wilting point. Continuous removal of water by plant roots causes gradual thinning of the soil moisture films around the particles and most of the wedges of water between particles disappear. A situation will eventually be reached when water is tightly held by the soil particles. The roots will not be able to extract it at a sufficiently rapid rate to prevent irreversible wilting. At this level, the energy required to extract water from the soil is about 14-15 atmosphere or equivalent to a tension force needed to raise a column of water to a height of about 1590 cm.

Unusual wilting or drooping of the leaves early in the morning and late in the afternoon indicate that soil moisture has decreased to the level or at least near the permanent wilting point. Some plants, however, will not show signs of wilting but will exhibit other signs such as change in the color of the leaves *or* stem and decreased plant and fruit growth. In practice, it is very difficult to determine the exact soil moisture level at which plants wilt. Therefore, permanent wilting point concept should be used only as a reference. Permanent wilting point is the limiting moisture wherein plants are irreversibly wilted because of excessively low soil moisture content. In general, the soil moisture content (dry mass) is about 12 to 18% in fine-textured and **10%** or less in sandy soils.

Available soil moisture. The soil moisture content between field capacity and permanent wilting point determine the limits of capillary water. This is the form of moisture that is retained in the soil unless absorbed by the roots or lost through evaporation. It is called capillary water in the sense that it moves through the soil by capillary action whenever any two points in the soil differ in energy potentials. In practice, the upper 50% of the capillary water range (from field capacity to permanent wilting point), is generally considered as available water for plant use. This limit prevents plants from being unduly exposed to frequenl soil-moisture deficits because their effects are usually cumulative. If water is inadequate, the plants may be allowed to deplete the soil moisture to as low as **75%** of the capillary water range. This practice is allowed only as a strategy to save the crop when water is very limited, especially during critical growth stages.

At saturation, water occupying the large pores will be removed by gravity. Water at field capacity will be removed by direct evaporation and absorption by the roots. Sandy soil exhibits lower moisture content and narrower margin of difference between field capacity and permanent wilting point than clay soil. Clay soil can hold more water than sandy soil. Although clay soil generally exhibits slightly higher moisture at field capacity than loam soil. some clay soil exhibits much higher moisture at permanent wilting point than loam soil. Thus, some clay soil has less capillary or available water storage. This happens when clay soil contains more fine clay than either sand or silt particles and/or high organic matter which tends to seal the fine pores. Therefore, the following factors affect retention and movement of soil water: (1) **soil** porosity and pore size distribution as influenced by grain size distrihution and the aggregate structure of particles, **(2)** soil depth, **(3)** cation exchange capacity of the soil, **(4)** soil temperature, *(5)* soil organic matter content and (6) quality of the soil-water system.

Irrigation Methods

Typical irrigated areas such as those served by gravity systems in the Philippines normally exhibit different land features within their respective commands. Moreover, individual farms or fields within a command may exhibit differences in terrains (i.e., uniformity and gradient, soil fertility, soil depth, soil texture and structure, etc). Methods of irrigation must be suited depending on topography, the crops planted and availability of water sources.

Current efforts aim to entice more farmers to practice crop diversification after the wet season rice crop. Since the same rice fields (rainfed or irrigated) will be planted, a number of surface irrigation methods are described as follows:

Level borders and basin irrigation. lrrigation by basin method is done by applying water to a level plot surrounded by dikes or levees. It is especially adapted in nearly level lands (as in lowland rice paddies) and may be used to irrigate a wide variety of soil texture and crops. This method is particularly suited for fine-textured soil with low permeability where it is necessary to hold water on the surface in order to insure adequate infiltration.

Level borders or basins, may vary in shape and size. During irrigation, basins are filled with water to a predetermined depth that will sufficiently refill the storage reservoir of the soil.

Contour levee ***irrigation.*** Irrigation water is applied to nearly horizontal areas confined by levees constructed following contour lines. This method is usually used in areas where slope is greater than **0.20%** but not higher than **4.0%** and where levelling would be impractical and expensive. The distance between levees depends on slope and crop to be irrigated. Difference in elevation between adjacent levees range from **3-15** meters. The contour levee method is well suited to lowland rice and any crop that can tolerate flooding for 12 hours or more. Irrigation water must be available at high flows in order to allow enough flooding of the area. Good drainage facilities must also be provided to drain excess water.

Contour-levee irrigation maximizes the use of rainwater. High efficiency can be achieved by this method provided the soil is not porous.

Contour ditch irrigation. Controlled flooding from field ditches running along the contour allows water to flow down the slopes between adjacent field ditches without employing dikes or other means to guide or restrict its movement. The field ditches should be spaced fairly close to each other in order that the irrigation water can be applied uniformly. Frequent ditch-checks, spreader furrows or siphons in the ditch are needed for uniform distribution of water. The contour ditch method is often used for close-growing crops such **as** pasture crops. It is also ideal for sloping and rolling lands which cannot be easily levelled.

Furrow irrigation. Crops planted in rows such **as** corn and vegetables can be irrigated by the furrow method. Water is applied in the furrows which are made by cultivating the spaces between the plant rows. Furrows usually run directly down the dopes, but can also run on the contour (basin furrows) to control erosion. Furrows may also be established across the slope for a rectangular and for uniform row length. Spacing between furrows depends on the crops planted. When irrigating, water must not overflow so **as** to minimize the breakdown of furrows.

Furrow irrigation is adaptable to a wide variation of slopes and soil textures. This method can be used with either large or small streams of irrigation water because water can be directed into any number of furrows directly from a farm ditch (or field) or gated pipe. The soil in the furrow is generally **loose** from cultivation and, therefore, care should be employed to control the flow of water in the furrow so that it does not develop an erosive velocity.

Excessive water losses will occur from deep percolation if the furrows are too long. The initial stream should be large enough to run through the furrow rapidly without erosion but should be reduced to minimize tailwater runoff **as** irrigation progresses.

Furrow irrigation is also used by farmers to irrigate crops planted on raised beds or ridges on nearly level lands similar to a lowland rice field. The beds or ridges are made by either plowing the land to form the beds or making deep furrows in the tilled land. It is best suited to irrigate garlic, onions and certain species of vegetables.

Corrugation irrigation. Shallow furrows running down the **slope** from head ditches or lateral canals are called corrugations. Corrugations are used to irrigate close-growing crops like bean crops, garlic and onions. The water flows laterally through the soil, between corrugations. This method is used in fine-textured soil that absorb water slowly and on lands that are moderately steep and irregular. Corrugations are also established on soil which seal over and crust when flooded.

The spacing and size of the corrugations vary depending on the crops. Generally, closer corrugations are established in more porous soil to prevent excessive deep percolation losses. Length of corrugation depends largely on soil type and **slope.** Lengths should be short enough ***so*** that the upper end of the field would not he over-irrigated by the time the lower end receives sufficient water. Corrugations are often used to establish perennial crops on border strips.

There are other irrigation methods available but were not included in the discussion. The methods enumerated above are the most likely methods to be used in crop diversification in typical lowland ricefield. The other methods are more complicated and expensive **for** ordinary farmers.

Crop production and irrigation management

The yield potential of a crop is determined by its genetic characteristics and its adaptability to actual field conditions. Crops differ in soil. water, solar radiation and other climatic requirements for optimum growth and yield.

Temperature determines the rate of crop development and hence, length of total growing period. Some crops have specific temperatures and/or daylength requirements for initiation of growth and development. Furthermore, the quality of yield in some crops is influenced by temperature.

Crop growth and yield are affected by the total radiation received. At a given radiation and temperature, crops differ in their abilities to convert the total radiation received into yield. This difference has an important effect on how efficiently water can be utilized for crop production.

The amount and availability of water during a cropping season also affects crop production. Crops differ in their requirements too. As much as possible, the demand for water must be synchronized with its availability. However, demand and availability of water is difficult to synchronize because the latter is beyond human control specially during the dry season. Thus farmers have to consider the availability of water when planning their planting schedule.

The production and irrigation management required for corn, mungbean, garlic, and onions will be discussed. It is hoped that these guidelines can help researchers and extension technicians and the farmers how to improve their technical management skills.

Corn

Corn is an important crop both as food for man and feeds for animals. In the Philippines, about 25% of the population eat corn.

Corn can be grown under a wide range of climatic conditions provided that the mean daily temperature is above 15°C and frost-free. A successful corn crop depends on variety planted.

Planting and ***cultural management.*** Corn is planted in rows. Seeds are either sown manually or drilled along the rows. The average planting distance is 15-20 cm between hills and 50-75 cm between rows. Ideal population density ranges from 60,000-100,000 plants per hectare.

Two weeks after emergence, the plants are hilled-up to remove weeds and establish the irrigation furrows. Fertilizer may be sidedressed during this time by scratching the side hills with a hoe or pointed stick to create corrugations. The fertilizers applied must then be covered with soil to prevent wastage when irrigation is applied.

A second weeding and hilling-up operation is done usually about four to five weeks after emergence. This may be accompanied by another round of fertilizer application.

Corn performs well in moist soils but less in heavy clay and sandy soils. The soil should be well-aerated and welldrained since corn is susceptible to waterlogging. If the soil is saturated or flooded for more than 24 hours, the plant may be physiologically disturbed as may be shown by discoloration of the leaves. If the excess water cannot be evacuated soon enough, plant growth will be stunted because of the absence of oxygen in the rootzone.

Corn is a high nutrient-consumer, requiring 200 kg Nitrogen (N), 60-80 kg Phosphorus (P) and 60-100 kg Potassium (K) per hectare. Unless adequate fertilizer is applied, it is not advisable to plant another crop of corn immediately after the first crop. Instead, leguminous plants should be planted to replenish soil nutrients.

Irrigation requirements and water management. Furrow irrigation is the usual method of irrigation for corn. Under ordinary conditions, an evapotranspiration rate of 5-6 mm/day is a safe estimate of the rate of soil moisture depletion. Irrigation interval is determined by dividing the depth of available water by the evapotranspiration rate.

It is good practice to synchronize fertilizer application with irrigation schedule. Also, the amount of irrigation water should be predetermined to avoid wastage of both nutrients and water, either through deep percolation or tailwater runoff at the end of the furrows.

In corn production, water must be available especially at flowering stage although corn can tolerate drought conditions at vegetative and after ear formation. The amount of irrigation is gradually reduced as the plant matures.

Under conditions of marginal rainfall and limited irrigation water supply, the number of irrigation schedules may vary from two to five depending on the severity of the water deficit. Therefore, irrigation schedules should be planned to take into account various growth stages of the plant.

Mungbean

Mungbean is grown primarily for its seeds. It thrives well in areas with medium rainfall. During the dry **season,** the crop can grow favorably provided that, there is enough water.

Planting and cultural management. Excessive rainfall and hot climate results in shattering of flowers and pods as well as increase in the incidence of pests and diseases. The optimum daily mean temperature for mungbean ranges from 15-20°C. The minimum and maximum temperature are 10°C and **27°C,** respectively.

Mungbean can be grown in any type of soil, however, friable and semi-acidic (pH 5.5-6.0) are preferred. For optimum production, 20-40 kg-N, 40-60 kg-P and 50-120 kg-K are applied per hectare. Although, mungbean is capable of fixing nitrogen, applying fertilizer at sowing will stimulate early establishment of the young plants.

Mungbean can be planted in two ways - broadcasted or drilled. Regardless of the planting method, plant population should be maintained at about **250,000-300,000** plants per hectare. Mungbean is usually planted as seeds or pre-germinated seeds a few days before or soon after the rice crop is harvested. Rice straw which is usually left in the field are pressed to the ground to serve as mulch to control evaporation of water and regulate soil temperature during early plant growth. On the other hand, mungbean is drilled if the field is cleared of plant debris. With zero tillage, a pointed wooden stick is used to dibble holes on the ground at random. Holes are dibbled 20-25 cm apart, with 2-3 seeds/hole. The residual soil moisture may still be able to permit emergence of pre-germinated seeds.

If residual soil moisture is low, it is better to plow and harrow thoroughly, then construct furrows. Mungbean are then drilled at the top or below the furrow ridge as in the case of corn. Distance between furrows ranges from 3040 cm while distance between hills ranges from 10-15 cm. First irrigation is applied after sowing.

When imgating mungbean, water supply should be strictly controlled. Weeds, pests and diseases should also be controlled. Thinning must be done to maintain the ideal plant population; dead plants must be replaced otherwise.

Irrigation requirement and water management. Mungbean is relatively a dry crop, requiring only about 200-300 mm of water. It cannot tolerate high soil moisture especially during seeding and establishment stages. Imgation can be applied by flooding in the case of broadcasted or drilled mungbean seeds without furrows and by furrow irrigation for furrow-seeded plants.

Where flooding is used, it is a good practice to construct deep trenches at each side of the field to drain excess water.

Water supply should meet the water requirements during crop establishment and flowering periods as these are critical stages. Plants subjected to water stress have dark blue leaves. As a guide, an evapotranspiration rate of 4.0-5.0 mm/day is sufficient to produce a good crop of mungbean.

Mungbean is shallow-rooted. Its fibrous roots are distributed within the rootzone at 0.50-0.70 meters deep. With adequate water supply, frequent irrigation is necessary.

Garlic

Garlic, a bulb crop is known for its varied uses in food preparations and medicine. Garlic is the most profitable dry seasoncropin northern Luzon particularly, in the provinces of Ilocos Norte and Ilocos Sur.

Garlic grows on various soil types but can perform best in sandy loam to silt loam soils. The soil should be fertile and welldrained but capable of maintaining adequate soil moisture during the growing period. Poorly-drained soils retard bulb formation. Since garlic is usually planted after rice, deep drainage ditches should be constructed on both sides of the field to drain excess water. Ditches are indispensable in fields within the command of an irrigation system.

The optimum soil pH for garlic is about 5.5-6.5.

Planting and cultural management. Land preparation for garlic can be done with or without tillage. With tillage, the field is plowed twice at 7 day interval. Each plowing should be followed by two harrowing operations. Land preparation using a rotavator is also applicable, depending on the density of weeds.

Without tillage, garlic is immediately planted after plant debris and stumps from the previous crop have been removed. If the previous crop is rice, straw and weeds are cut close to the ground. If the field is saturated, it should be dried to about field capacity before planting the seed materials which are then covered with mulch. Some farmers mulch and dry the rice field before seeding. The ideal time for planting garlic is in early October to November. Seed cloves are soaked for one hour in pesticide solution before planting.

Garlic is dibbled into the soil using a pointed stick. Depth of planting is 2-3 cm. Planting distance ranges from 20 X 20 cm to 25 X 25 cm, depending on soil fertility. To assure good soil-clove contact, the soil is pressed around the cloves using the thumb and forefinger.

Fertilization should only compensate the native fertility of the soil. In Ilocos Norte, the recommended rates of fertilizer applications are: 90 kg-N, 60 kg-P and 60 kg-K per hectare for sandy soil; 80 kg-N, 60 kg-P and 60 kg-K per hectare for clay loam soil and 80 kg-N, 30 kg-P and **30** kg-K per hectare for clay soils.

Once planting and mulching have been completed, it is necessary to monitor the germination and emergence of the plants. Dead seeds should be immediately replaced. The mulch should not obstruct the emerging shoot.

Weeding should be regularly done to avoid competition for nutrient and water between crop and weeds. Emergence of pests and diseases should be immediately checked. Severely infected plants must be pulled and burned to avoid spread of the disease.

Irrigation requirement and water management. Garlic requires about 200-400 mm of water during the duration of its growth. Irrigation is applied by flooding the field at regular intervals since the crop is sensitive to wet environment. Excess water should be removed by trenching along the inner sides of the dikes. It is a common practice to irrigate garlic with **5** cm of water every two weeks, starting at planting until about 85 days afteremergence. Some irrigation schedules may be suspended, especially during periods of limited water supply. A modified version of furrow irrigation can be used provided that garlic is planted on 1.5-2.0 meter wide raised-bed. Since water is applied to the trenches between beds, it reaches the rootzone by capillary action.

Onions

Onion is another profitable dry season crop in the Philippines. Like garlic, it is planted after wet season rice. It has a variety of uses for food seasoning and for the manufacture of medicines.

Planting and cultural management. Bulb onion is grown from seeds. There are a number of improved varieties that are presently grown commercially, specially in Nueva Ecija.

Onion grows best in friable, fertile and well drained soil. Loamy soil with a pH of 5.5-6.5 is ideal for onions. Onion also grows best in cool weather during the early stages of growth and a comparatively dry atmosphere (with high temperature) during maturation. The crop is planted from October to December when the soil still retains a considerable amount of residual moisture from the previous rice crop.

Land preparation for onion is similar to that of garlic except that most farmers grow it in raised beds for better control of soil moisture at the rootzone.

Onion is first grown in nursery beds for about 6-7 weeks, and after which, it is transplanted to the field. Planting distance is **25** cm X **25** cm. About **3-5** kg/ha of seeds are needed to cover one hectare, i.e., depending on percent germination.

Bulbs are dibbled into the soil at 1-2 cm deep using a bamboo stick. Field/plots planted to onions are mulched. A moderate amount of water is applied directly to the plants to prevent wilting. An alternative is to irrigate the mulched field **3-5** days before transplanting. Extreme care should be exercised while planting the seedlings so that the soil does not become compacted.

Fertilizer requirement and fertilizer management is similar to that of garlic. Weeding, pest and diseasecontrol measures should be observed properly.

Irrigation requiremenr and water managemenr. Onion is sensitive to water deficit especially during transplanting, bulb formation and development. For high yields, soil water depletion should not exceed 25% of the available water. When the soil is relatively wet, root growth is reduced which favors bulb enlargement. Irrigation should be discontinued as soon **as** the bulbs are fully developed to desiccate the plant tops and prevent the formation of new roots. For optimum yield, onion requires about **300-400** mm of water during the growing season. Rapid bulb growth occurs at about 60 days after transplanting. At vegetative stage, the crop is less sensitive to water deficit. Controlled and frequent but light irrigation throughout the growing period is best for the crop to achieve high yield. Over-irrigation. leads to reduced growth. Irrigation can be terminated **15-25** days before harvest.

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