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Technical manual for wheat planting in Sub-Saharan Africa



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Table of Contents

A role for wheat in Sub-Saharan Africa

The annual consumption of wheat in Sub-Saharan Africa is following an upward trend. Compared to the demographic increase of the African population that registered a + 32% since 2007, in the same time span the continent's wheat imports increased by 68%, to reach 47 million tons in 2019. This is due to the low price of bread on the market combined with the facility of its consumption. Along the same trend, durum wheat foods in the form of pasta, couscous, and burghul (broken grains) has also been rising steadily. On the other hand, very few African countries produce this crop in good quantity, so most of its consumption is done by paying for expensive international imports.

There are two type of wheat that are consumed: common or bread wheat is the most widely imported since it is the most suited for producing raised breads, while durum wheat is primarily used for transformation into couscous, pasta, and burghul. Also, bread wheat prices are typically 20-30% inferior to those of durum, and its nutritional value is also inferior. In terms of production, both crops are suitable for cultivation in Sub-Saharan Africa. To date, in side-by-side comparison trials durum has resulted in slightly higher yields and better resistance to some of African devastating diseases. Finally, durum is also suitable for the production of bread, especially when used as mixtures.

The combination of better prices, better options for use by the industry, higher yields, and better disease resistance has promoted the production of durum wheat in West Africa, but it is not so in East and South Africa where bread wheat remains the most cultivated of the two. For review see: *Sall AT, Chiari T, Legesse W, Seid-Ahmed K, Ortiz R, van Ginkel M & FM Bassi. 2019. Durum wheat: origin, cultivation, and potential expansion in Sib-Saharan Africa. MDPI Agronomy, 9:263.*

This manual covers the technical aspects linked to the cultivation of both crops.

The stages and requirements of the wheat crop

Wheat is a very plastic crop capable of adapting to extreme conditions. Its ability to produce high yields is linked to the availability of soil moisture and nitrogen fertilization. With the development of heat tolerant varieties, the maximum day temperatures that can be withstand by the crop have increased from 32° C to over 42° C. Exceptional days above these temperatures can also be tolerated, with some detrimental effect on the yield, especially if these occur during the flowering period. The best season to grow wheat in SSA is the winter, to get minimum of cold allowing good development of the crop. The best crops to precede wheat are legumes and tubers, but wheat can be grown after rice or fallow.

The wheat crop cycle can be divided in six major steps:

1. Germination
2. Vegetative growth or tillering
3. Stem extension
4. Flowering or heading
5. Ripening
6. Maturity

Each of these steps is affected by the environment and hence needs to be considered for cultivation. In Figure 1 are presented some of the minimum requirements and ideal conditions for the crop.

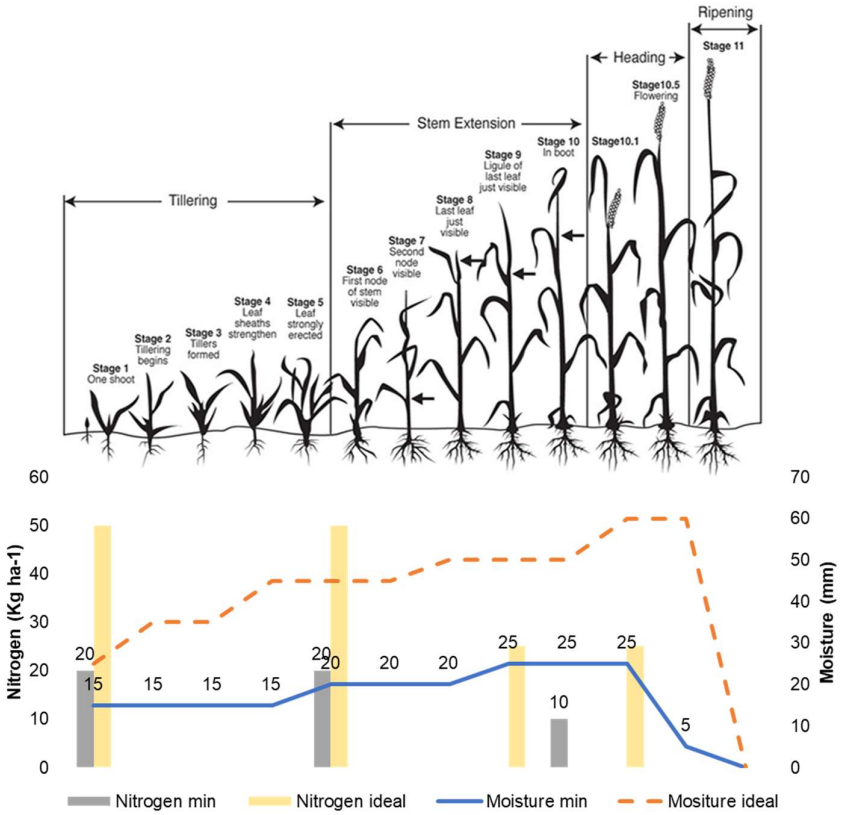

Fig 1. Minimum requirements for a wheat crop of 1-2 tons per ha yield

In order to germinate, the wheat seeds need to receive at least 10 mm of moisture. In most soils, at least 5 mm of the water provided will be dispersed through evapo-transpiration and hence will never reach the grain. The vegetative phase of the wheat plant is very important as it determines the final biomass. During this phase, at least 65 mm of moisture needs to be obtained. The stem elongation ensures the production of fertile wheat spikes/heads. The plant has become bigger and hence it requires more moisture. Typically, 90 mm is the minimum requirement to maintain average productivities. The following phase determines the number of grains that will be produced in each spike. The length of this phase is shorter, but 25 mm of moisture are required. In the ripening phase, the size of the grains is defined. A minimum requirement of 5 mm of moisture guarantees the completion of the cycle. After this point the wheat plant can proceed to full maturity with no moisture. Hence, 200 mm of moisture are necessary to complete the full wheat cycle even when using drought and heat tolerant varieties.

***Moisture calculation**: 1 mm of rainfall is equivalent to 1 liter of rain water per 1 m^2. Hence, to provide to a surface of 1 ha the equivalent water of 1 mm, it is necessary to irrigate with 10,000 liters. For example, an affordable 1.5 HP fuel pump provides 3 liters per second. 1 hour of operation would be required to irrigate 1 ha with 1 mm and 10 hours for 10. A 4 HP diesel pump provides 30 liters per second, so 30 min would be necessary to irrigate 1 ha with 10 mm.*

In addition, the wheat crop can not produce adequate yields in absence of synthetic nitrogen fertilization. The minimum amount is 50 Kg per ha, ideally distributed over 2 or 3 applications. The most critical is the fertilization before planting and at the end of the vegetative stage. An additional split application can be made before flowering when looking to produce a crop with top quality for the market.

The Sub-Saharan Africa "new" agro-ecologies

The African continent is defined by drastic differences in terms of climates, soils, and several other conditions. To expand the wheat cultivation to these areas, the characteristics presented above need to be respected in order to obtain a profitable harvest. Two main agro-ecologies can then be defined based on their availability of moisture.

Irrigated Savannahs in between rice crops

In several African countries especially in the West, rice is the main crop. It is cultivated once or twice per year taking advantage of irrigation water, heavy seasonal rainfall and warm temperatures. Wheat cultivation is not suitable as a replacement for rice because it does not withstand the high moistures. Instead, the use of fast-growing heat tolerant varieties is ideally suitable for providing a rotation crop with planting in between rice crops. In most West African countries, there is no rice cultivation between the months of December to March. This 110 days window can then be exploited for wheat. *Under these conditions water is not a limiting factor, daily temperatures are often above 38° C, and the varieties must be very early maturing to avoid shifting the rice operations.*

Residual moisture lands

Heavy downpours are common throughout the rainy seasons in most of the African equatorial and tropical countries (**Fig 2**) with annual rainfalls that often exceed 1,000 mm.

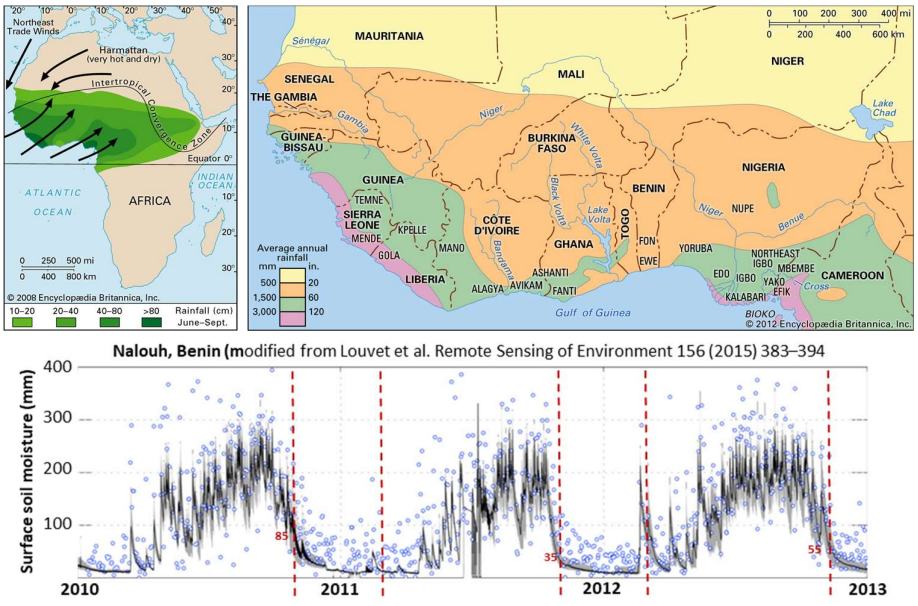

Fig 2. Annual rainfall in West Africa and surface soil moisture in Central Benin

This moisture is mostly used for cassava, cotton, maize and other crops. However, the period that follows the rains is typically left fallow or for grazing of animals. It is in this period that the cultivation of wheat should be sought. Surface soil moisture (0-5 cm) was measured as superior to 30 mm at the end of the month of October in Benin, and similar values can be expected in most countries experiencing similar amounts of rainfall. This value is sufficient to guarantee the germination of the wheat seeds. In addition, the deeper soils should maintain good amount of moistures for a longer period. If the wheat plant can grow its roots in this moist soil it would not need the provision of additional water to achieve 1-2 tons per ha yields. *Under these conditions water is the main limiting factor so drought tolerant cultivars with early growth and deep roots should be preferred. Early maturing is also a preferred trait to avoid the end of the cycle (February) when no more moisture can be found.*

Cultivation practices

As per the wheat cycle, the agronomic practices follow the cycles of the wheat plant and can be defined as:

1. Soil preparation
2. Planting
3. Weeding
4. Fertilization
5. Irrigation
6. Harvest

The specific aspects of these practices will be described for the two agro-ecologies. In addition, mechanization is often limited in Sub-Saharan Africa, so both traditional and modern practices will be presented.

Irrigated Savannahs in between rice crops

Soil preparation

The lack of time for the shifting between the rice and the wheat cultivation represents one constraint. Also, the wheat crop, differently from rice, suffers severely if the water is left stagnating in the field. Hence, it is critical to have good leveling of the soils to ensure rapid exit of the irrigation water.

Mechanization available:

The availability of a tractor mounting a simple disk harrow (**Fig 3**) can be used to work and homogenize the soil after the rice season. This type of treatment can reduce the amount of weeds present in the field. However, it will also require the precise leveling of the field after the work is completed. Laser leveling (**Fig 3**) is the best approach for this. Affordable implements can be purchased from India for that scope and can also be used for rice cultivation. In absence of the leveler, it is necessary to fill the soil with irrigation water and smooth the surface using a shovel. The water should then be exited and the soil allowed to dry before planting.

An alternative is the use of “raised beds” (**Fig 3**), which are substantially small channels dug into the soil, not different than those used for potatoes or onions. These channels will then be used to

irrigate, avoiding the work of leveling the soil. “Raised beds” can be made using a machine or by hand. Again, affordable implements for “raised-beds drills” are available from India

Fig 3. Mechanization implements: disk harrow, laser leveler, and raise-beds harrow.

Mechanization is not available:
The timing is a major issue as only few weeks can be used to change from the rice to the wheat cultivation. In absence of mechanization it is then best to leave the rice in the field as it is, without working the soils (**Fig 4**).

Fig 4. Soil ready for planting after leveling and provision of 1 irrigation

Planting

Differently from rice, wheat cannot be planted directly in the water. Instead, it needs to be covered with 4-6 cm of soil and water provided to favor germination.

Mechanization available:
Tractor mounter seeders are ideal to ensure correct distribution of seeds and even planting depth (**Fig 5**). These implements should be set to deliver 100-120 Kg of seeds over a surface of 1 ha (100 m x 100 m). If available, a combined raised-bed planter should be used. Also, 2-wheels small seeders are also available at an affordable price from China and India (**Fig 5**).

Fig 5. Seeding activities by two-wheels seeder, tracing furrows by hand, and germination of wheat.

Mechanization is not available:
In this case hand broadcasting should be used. The seeds should be cast with good strength toward the soil, and covered with a thin layer of soil (2-4 cm). The seeding rate should be increased to 200 Kg of seeds per ha. To facilitate the weeding work, it is best to try and cast the seeds into rows by first opening furrows (**Fig 5**).

Weeding

This practice is very important, especially in the initial and final stages of the crop. Differently from rice, wheat is not grown under water, so the weeds can proliferate very easily. To prevent these taking over, it is advised to use herbicide treatments. 2,4-D is very effective against broad leaf weeds. The market should be scouted for wheat-ready herbicides to control narrow leaf weeds. In absence of chemicals, it is important to conduct weeding regularly by hand using simple instruments. This is very important approximately 4-6 weeks after planting, and then again around the time of flowering (**Fig 6**). Ideally, the wheat has been planted in rows and then weeding can be done in between the rows facilitating the work.

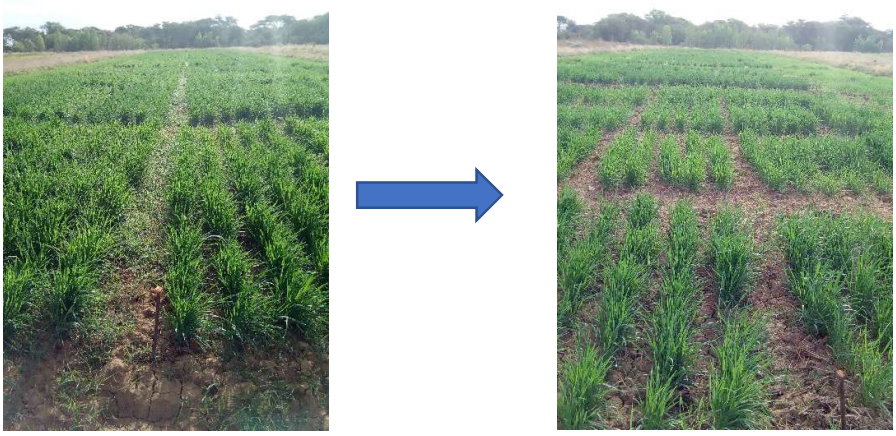

Fig 6. Hand weeding 4-6 weeks after planting

Fertilization

The wheat plant requires all three elements to be fully successful: N, P, K
For yields of 3-5 tons per ha it is advised to provide a total of 150 Kg of Nitrogen, and 50 Kg of P and K. To do so, the following rates should be applied

Before working the soil: 300 Kg of 15-15-15 NPK fertilizer or similar to provide 45 Kg of N, P, and K
Stage 3-5 vegetative stage = 3-4 week after planting): 100 Kg of Urea 46%
Stage 8-10 = 6-7 weeks after planting: 100 Kg of Urea 46%

To reduce costs, these amounts could be halved. It is important to know that P and K can NOT move from the surface of the soil to the roots of the plants. Therefore, the first fertilization must be done before working the soil to be incorporated inside the first 3-8 cm of soil. For hand planting, this fertilization can be done at the same time of planting. There is no scope to use an NPK fertilizer after the planting has been done.

Irrigation

Differently from rice, the wheat plant does not like to be fully covered by water for more than 1 day at a time. Water that stagnates 2-3 days results in yellow plants that often die out. To avoid this, it is very important to ensure that the irrigation water is provided in sufficient amount to cover the whole filed with 1-2 cm layer of water. Then the water needs to be allowed to evaporate quickly, or allowed to exit the field. To facilitate this, it is good to use a system of micro dams to create small-parcels of 25 m x 50 m in size and ensure equal distribution of irrigation water (**Fig 7**). A simplified schematic is presented in Figure 6: a 1 ha field is divided into 4 parts using small walls of soil approximately 5-10 cm high. The irrigation water is allowed to enter into 2 of these quadrants until approximately a thin layer of 1-2 cm of water covers the whole surface. Then the source of water is closed, and the bag of sand removed. The extra water will then enter the other 2 quarters of the field. At this point the bag of sand are placed again, and the two other quadrants receive direct irrigation. The process is repeated.

To obtain high yields, it is best to provide many small irrigations, rather few big ones. For that, a process of 2-4 hours of irrigation every 3-4 days is the one that provided for us the best results. Each irrigation should provide approximately 20-30 mm of water, depending on the pump power.

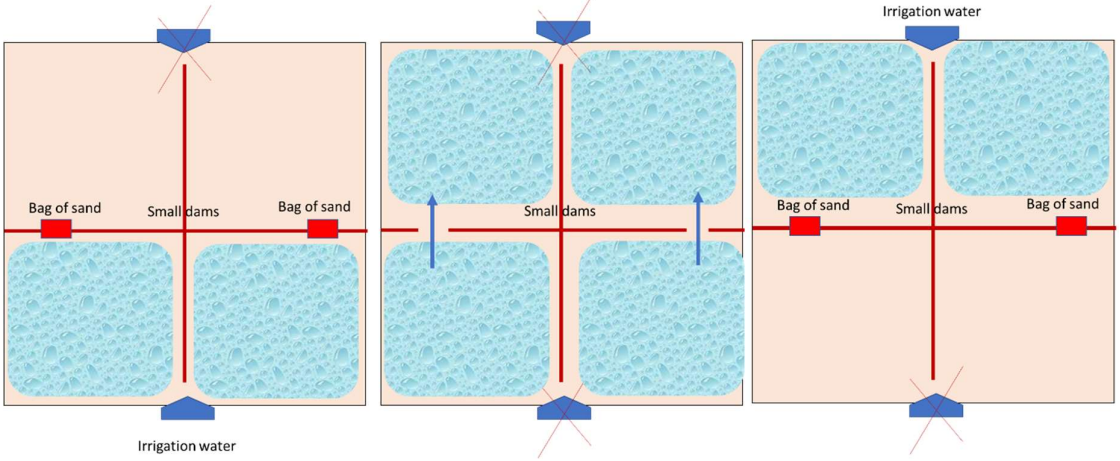

Fig 7. Strategy to ensure light irrigations of 20-30 mm of water each by dividing the surface in smaller parcels of 0.25 ha in size.

Harvest

Once the wheat plants become completely yellow and it is possible to thresh the spike using only the hands, then the crop is mature for harvest (**Fig 8**).

Mechanization is available:

The same machinery normally used for rice can be easily adapted for wheat. This typically include rather a combine harvester or a vertical thresher (Fig 8). For the combine harvester it is important to ensure that the machine is operated with low concussing strength, to avoid breaking the grains. Also, the sieves need to be regulated at a sufficient size to capture the large wheat grains. The same attention should be used for vertical threshers.

It is important to harvest in separate bags the different varieties to avoid seed mixtures.

Fig 8. Harvesting procedures at wheat maturity, threshing with a rice vertical thresher or by hand using bags and wooden sticks

Mechanization is not available:

As for rice threshing, it is also possible to thresh the spikes by hand. These should be placed inside plastic bags and then beat with sticks (**Fig 8**). Alternatively, the spikes can be placed in between cardboard sheets and threshed by hand using an up-down motion.

Calendar of operations along the Senegal River

Date	Operation
20-30 November	Prepare soil for planting by levelling of the field with one irrigation, and provision of 300 Kg of N-P-K fertilizer
1-10 December	Conduct planting, followed by 1 irrigation
general	Irrigated two times per week, approximately 2-4 hours each time depending on pump capacity
1-15 January	Conduct weeding by hand or chemicals. Provide 100 Kg of Urea
10-15 February	Conduct weeding by hand or chemicals. Provide 100 Kg of Urea
1 March	Stop irrigation once the stem of the wheat plant starts become yellow
15 March	Harvest

*The dates can vary depending on the temperatures and specific conditions

Residual moisture lands

Soil preparation

It is critical to maintain the maximum amount of moisture in the soil.

Mechanization available:

The availability of a tractor mounting a simple disk harrow (**Fig 3**) can be used to work and homogenize the soil before the last rains. This type of treatment can reduce the amount of weeds present in the field. However, the soil should NOT be worked just before planting because it would cause moisture to be loss from the soil.

Mechanization is not available:

Limit the work of the soil to the minimum and it should only be done before the last rain, to avoid losing moisture

Planting

They key for a successful crop is to:

1. Ensure that the seeds have the time to germinate before the moisture disappears from the top layers of the soil. To facilitate, the seeds should be **put into full immersion in water for 1 hour to favor their germination and planted right after**.
2. Ensure a planting depth of **5-7 cm to reach** the moisture in the lower layers.

Mechanization available:

If available a 2-wheels small seeder should be used to reach 5-7 cm depth of planting (**Fig 2**).

Mechanization is not available:
In this case hand broadcasting should be used. However, it would not be possible to reach enough planting depth to guarantee germination. Hence, thin furrows should be opened in the soil using a hook tool, and the seeds deposited inside (**Fig 9**). Then the seeds should be covered with the surrounding soil. The seeding rate should be 200 Kg of seeds per ha to account for the seeds that will not germinate.

Fig 9. Simple tools to open furrows of 5-7 cm in depth

Weeding

This practice is very important, especially in the initial and final stages of the crop. To prevent the weeds from taking over, it is advised to use herbicide treatments. 2,4-D is very effective against broad leaf weeds. The market should be scouted for wheat-ready herbicides to control narrow leaf weeds. In absence of chemicals, it is important to conduct weeding regularly by hand using simple instruments. This is very important approximately 3-5 weeks after planting to prevent the weeds from stealing moisture from the crop

Fertilization

The wheat plant requires all three elements to be fully successful: N, P, K
For yields of 1-3 tons per ha as it can be expected from this method, it is advised to provide a total of 60 Kg of Nitrogen, and 25 Kg of P and K. To do so, the following rates should be applied

At the time of planting, mixing the fertilizer with the seeds: 150 Kg of 15-15-15 NPK fertilizer or similar to provide 23 Kg of N, P, and K
Stage 3-5 (vegetative stage): 30 Kg of Urea 46%

To reduce costs, these amounts could be halved. It is important to know that P and K can NOT move from the surface of the soil to the roots of the plants. Therefore, the first fertilization must be placed in close proximity to the grains, 5-7 cm deep. There is no scope to use an NPK fertilizer after the planting has been done.

Irrigation

Water is extremely scarce under these planting conditions. One 20 mm irrigation should be provided 1 week after planting to maximize the chances of growing long roots fast. This can normally be done using the stagnating water reaming at the end of the wet season (**Fig 10)**. A second irrigation of 20

mm needs to be provided 4-6 weeks after germination (Stage 4-6) to maximize the biomass. A strategy needs to be put in place to transfer the wet-season moisture to the 2nd-3rd week of December

Collecting rain water: the rainfall during the wet season can reach up to 1100 mm. This means that a surface of 1 m^2 receives 1.1 m^3 of moisture. One irrigation of 20 mm for 1 ha requires 200 m^3 of moisture, which means we need to capture **the rainfall falling on 180 m^2 during the wet season to irrigate 1 ha during the dry season**. There are various methodologies to do so:

a. Digging 10 small basins: a hole of 5 m in diameter (approx. 20 m^2) and 1 m in depth (20 m^3) will receive during the wet season the equivalent of 22 m^3 of rain. Digging of 10 of these wells in areas of the field that are not cultivated will ensure enough water to irrigate 1 ha. The bottom and side of the well need to be covered with concrete or plastic tarps to avoid escape. Ideally the top should also be covered with a tarp during the dry season to reduce evapotranspiration.
b. Natural or artificial low points: each farm as areas of lower altitudes. These can be easily identified in the rain seasons as those points where water stagnates for longer. These areas should be marked during the rainy season and converted to water harvesting basin. It would be sufficient to dig 20 m x 25 m pools (500 m^2) x 2 m in depth (1000 m^3), ensuring that the edges are below the first soil layer (20 cm in depth). The basin would capture 550 m^3 of rain directly, and receive additional 450 m^3 as water run-off from the surrounding higher areas. An improvement could be to build declining concrete channels to favour capturing of moisture from more surface. One such pool would allow to provide 20 mm irrigation to 5 ha.
c. Irrigation basin: these can be built with limited digging, but construction machineries are needed for the construction. An irrigation basin of 20 m x 10 m (200 m^2) x 4 m (800 m^3) in depth is normally built by digging 1 m in depth and raising soil walls of 3 m height, then covering everything with a plastic tarp. This basins would collect 220 m^3 of rain water. To complete the remaining requirement in water, this has to be obtained by capturing water from rivers or other sources. One basin would allow irrigating 4 ha with 20 mm.

Collecting underground water: this is a very precious resource and it is suggested to use it only as last resource during particularly dry years, or to provide drinkable water to humans and animals. The water table in West Africa indicates that water is often available 20-30 m below the surface. A solar or a wind-powered pumping systems are ideal to extract the underground water. However, none of these two methods guarantee enough water pressure to be used directly for irrigation. Even the use of drip irrigation requires 1 bar of pression, and this can not be reached by these types of pumps. Therefore, an irrigation collection basin needs to be filled using underground water. Afterward, a fuel or electrical pump need to be used to pump the water from the basin to the field. It would be important to have more than one well dug, to ensure a backup of water in case the first one dries out. Also, two wells would fill the basin much faster, allowing more irrigations.

Harvest

Once the wheat plants become completely yellow and it is possible to thresh the spike using only the hands, then the crop is mature for harvest.

Mechanization is available:

The same machinery normally used for rice, millet or corn can be easily adapted for wheat. This typically include rather a combine harvester or a vertical thresher. For the combine harvester it is important to ensure that the machine is operated with low concussing strength, to avoid breaking the grains. Also, the sieves need to be regulated at a sufficient size to capture the large wheat grains. The same attention should be used for vertical threshers.
It is important to harvest in separate bags the different varieties to avoid seed mixtures.

Mechanization is not available:
As for rice threshing, it is also possible to thresh the spikes by hand. These should be placed inside plastic bags and then beat with sticks. Alternatively, the spikes can be placed in between cardboard sheets and threshed by hand using an up-down motion.

Fig 10. Water trapping solutions (well, low point, basin, and solar pump)

Calendar of operations for residual moisture planting (Benin)

Date	Operation
20 May	Dig water trapping systems
1-15 June	Prepare soil for planting by working the land and remove weeds
20-30 October	Soak wheat grains for 1 ha in water, conduct planting in 5-7 cm deep furrows incorporating also 150 Kg of N-P-K fertilizer
10-20 November	Irrigated with 20 mm using stagnating water or rivers
1-15 December	Conduct weeding by hand or chemicals. Provide 50 Kg of Urea
15-20 December	Irrigate with 20 mm using “water trapped” from the wet season
15 January	Conduct weeding by hand
1-15 February	Harvest

*The dates can vary depending on the temperatures and specific conditions