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Experiences with Road Runoff Harvesting and Agroforestry in Kitui and Machakos county, Kenya

Practical Note

Flood-Based Livelihoods Network Foundation

1. Introduction

Road runoff harvesting (RRH) is a practice of which its integration is not yet widespread, especially in Kenya. It is mostly practiced in the ASALs in Kenya. The ASALs constitutes about 80 percent of Kenya's land area which supports 50 percent of livestock population and 35 percent of human population (Mutunga, 2001). RRH is a technique that results in increased land productivity and environmental sustainability. Land productivity is the ability of land to produce specified outputs under given management conditions, but also being subject to factors such as climate, topography and drainage (Gachene and Kimaru, 2003). Ecosystem sustainability can be defined as meeting the resource and services needs of current and future generations without compromising the health of the ecosystems (Morelli, 2011).

This RRH technique of soil and water conservation is relatively new to researchers and development agencies. Road run off harvesting is a form of rainwater harvesting where surface runoff from roads is collected and diverted to croplands and pasture lands. The surface runoff is deliberately channeled into various soil and water conservation structures, especially the *fanya juu* terraces and retention ditches (Ngigi, 2003). However, there are other options used to collect water from roads and they include; diverting water from culverts, channeling mitre-drains into farmlands and deep trenches. A RRH system is composed of; a cutoff, that diverts the runoff directly from the road, a retention ditch, for storing road runoff, terraces for conveying road water to individual crops and trees, and finally a farm pond, which is optional. These techniques of water harvesting have proven successful for smallholder farmers in ASALs in Kenya for example in Kitui, Machakos and Makueni, where the farmers have had substantial increase in yields and income.

Figure 1 shows the principle of rainwater harvesting and management system, which as the following components:

1. Collecting and concentration of runoff.
2. Storing runoff (optional).
3. Using run off for agricultural production (Ngigi, 2003).

The catchment area is formed on the road or the side of the road where rain water or flash floods pass. Once the water reaches the agricultural field it is conveyed to individual crops or trees by the use of trenches, bunds and terraces. Aside from growing of crops, agroforestry can be integrated in the farming system. Trees can be planted in the terraces, or trenches where water is conveyed. They can also be planted in soil bunds dug in the field. The tree species selected have to be water tolerant and nutrient adding to the crops e.g. nitrogen-fixing trees. In order to stabilize the soil, grasses and fodder can be planted on the embankment to avoid erosion.

Crops with high water requirements, such as bananas, are often grown in the terraces, where water is collected and retained (Black *et al*. 2012). Agroforestry trees including fruit trees, fodder trees and hardwood trees can also be integrated into the system. This ensures an increase in agricultural production through; increasing soil nutrients utilized by the crops e.g. for nitrogen fixing trees and provision of fodder for livestock. The leaves of the trees can also be used as mulch to further increase nutrients in the soil. Agroforestry is considered an appropriate land-use system for ASALs to ease food, fuel, fodder and timber shortages and improve soil conditions. The positive effects on the soil are based on the penetration of strong roots to deeper layers to bring up plant nutrients, enrichment of the soil in humus and nutrient content, and on the improvement of the nitrogen status of the soil (Gachene and Kimaru, 2003).

This practical note highlights the effects of RRH and agroforestry on land productivity and agro-ecosystem sustainability. More specifically, it assesses how integration of agroforestry will increase land productivity and agro-ecosystem/ environmental sustainability, and to determine the effects that road water harvesting has on agricultural productivity in relation to increasing yields. The results are based on farm visits to Kitui and Machakos Counties, where farmers practice road water harvesting and agroforestry.

Figure 1: A simple illustration of the principles of rainwater harvesting

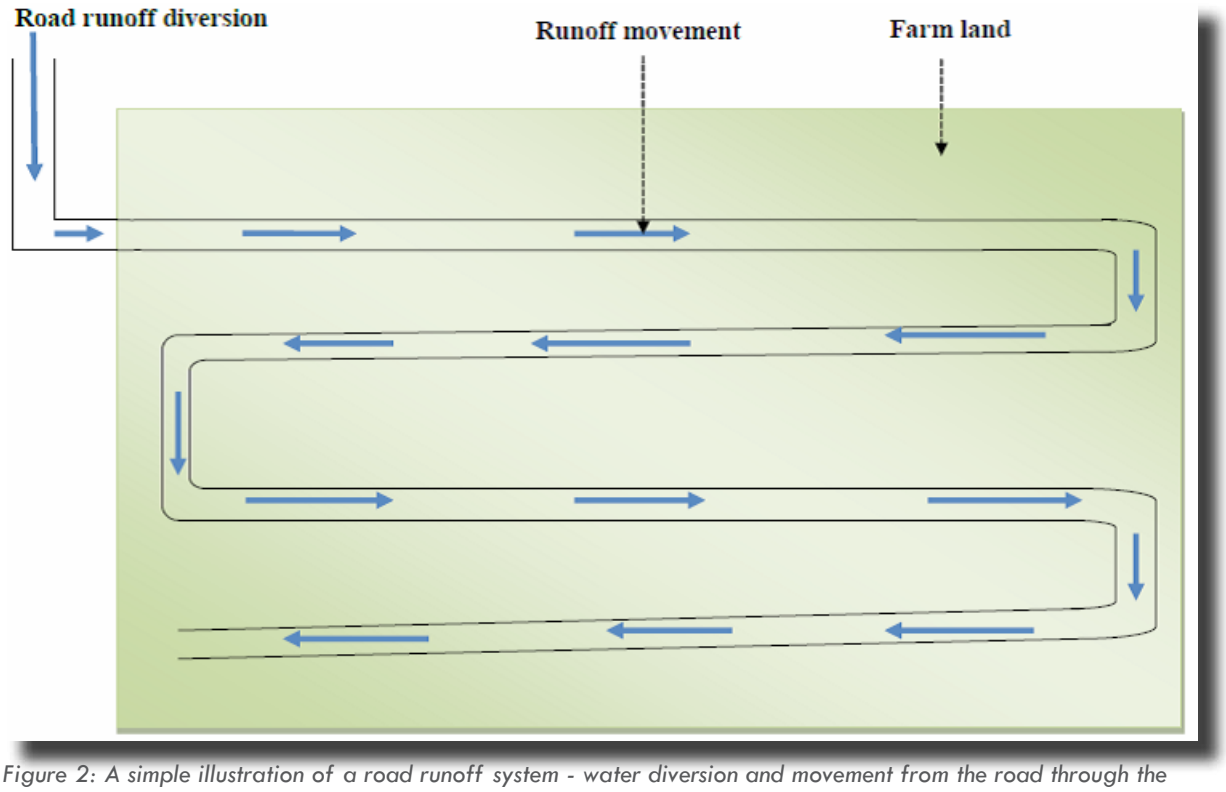

Figure 2: A simple illustration of a road runoff system - water diversion and movement from the road through the terraces in the farmland

2. Practices in Kitui county

Kitui, particularly Kathome and Kawongo sub-locations were chosen as the areas of study because of the practice of agroforestry. Six farms were visited, accompanied by a project team of MetaMeta. In these farms, agroforestry was more widespread compared to RRH. On the way to Kathome location, there is a river known as Tiva River. It is a seasonal river which was dry. Most farmers in this area get their water from the river. The seasonal river, which can also be called a wadi, has a potential for inundation canals to divert water into the farms. This opportunity for spate irrigation has not been explored in this area. There was gulley formation on the roads as a result of land degradation. The following are the farms visited in Kathome and Kawongo sub-locations in Kitui County.

Farm of Mr. Geoffrey Musyoka

The manager of this farm located in Kathome sub-location is Mr. Geoffrey Musyoka. He started working in the farm three years ago, though the farm was started in 2010. The tree species found in this farm are *Melia volkensii* (commonly known as *Mukau*) and *Azadirachta indica* (neem tree). Most farmers in Kathome are growing *Melia volkensii* for commercialization purposes. This tree has strong, durable and more expensive timber than the *Grevillea robusta*.

Figure 3: Melia volkensii and Neem trees intercropped with bananas

These trees were supplied through a local group known as the Forest Market Foundation, and they are grown in association with bananas, pawpaw, cow

Figure 4: Mr. Musyoka crushing the pods to get the seeds of the Melia volkensii

peas. This foundation was created by farmers so that they can access seedlings. The farmers do not buy seedlings instead they get the trees directly from the tree and the seeds are then germinated in a nursery so as to be planted. The seeds are plucked directly from the trees and since the seeds are usually in pods, as shown in Figure 4, the pods are crushed to release the seeds. The seeds are then soaked in water, to break the seed dormancy, and to ensure faster growth. The seeds are then transferred to a seed nursery in a greenhouse structure where they are planted on sand soil so that they can germinate. The sand soil is lined with a nylon paper to reduce water loss since sand soil is highly porous. Chemicals are also used to get rid of microbes. It takes one week (7 days) for the seeds to germinate.

The *Melia volkensii* tree is drought, termite and pest resistant. According to Mr. Musyoka, legumes grow better when intercropped with the tree as opposed to maize. This was discovered when the tree was grown in association with maize, the maize was stunted and did not produce abundant yields. However, when grown in association with legumes, especially cow peas, there was increase in yields by about 30%. Since Mr. Musyoka does not practice RRH, his source of water is from an underground tank found on the lower section of the farm.

There is a certain age where trees are not intercropped with crops, for example, when the tree has the biggest canopy. Therefore it is better to get advice from experts in Kenya Forestry Research Institute, or other forestry organizations, on the age when intercropping should be done.

Farm of Mrs. Rose Mlaa

Mrs. Rose is the chairlady of the Forest Market Foundation in the area. The farm is five acres in size and she also has *Melia volkensii* and neem trees. She noticed an increase in yields of pigeon peas by approximately 25% when she planted them in the section of the farm that has trees. This is probably because the trees are able to grow deep in the soil thereby making the nutrients found deep in the soil available to the pigeon peas. Once the trees are mature, she uses the trees for timber, which she also sells and for construction. The sale of the timber acts as a secondary source of income. The trees also have aesthetic value since they beautify the farm and improve the environment.

The main problem that she faces is the feeding of the trees by animals. Due to lack of fencing, most of her trees have been eaten by goats. She has also attempted to harvest road water, though it

Figure 5: The seeds are soaked in water to break seed dormancy

Figure 6: A young Melia volkensii tree in Rose's farm

Figure 7: A cutoff to divert road water either directly into the farm or storage (farm pond

has not been effective. This is because she lacks terraces to convey the road water into the farm. There is one trench from the road into the farm but the water does not spread to the farm and hence she does not utilize the road runoff. However, by October this year she is planning to dig terraces in the farm so as to convey the road runoff.

Farm of Mr. Priscah Mutia

Mr. Mutia, the owner of the farm, practices RRH and agroforestry. He has *Melia volkensii* trees that, according to him, do not have any negative effects on maize. He also has fruit trees e.g. Mango, Orange and Pawpaw. He has also planted food crops e.g. maize, beans and pigeon peas that have all had increases in yields by about 20%. The main challenge he has faced is the trees bring eaten by goats, and this has led him to fence his farm. Mr. Mutia started practicing RRH in 2007. He dug a cutoff, terraces and a farm pond. The farm pond did not have any water this was because it did not have a lining, hence making it ineffective for storing water.

His farm is different from other farms in the area that do not harvest road water. This is because his farm has retained water as opposed to others. One of the reasons he harvests this water is because during heavy rains, the water floods and destroys the roads. There are some few farmers in the area that also harvest the road water.

Figure 8: Mr. Mutia illustrating how the road runoff is diverted into his farm

Farm of Mrs. Diana

In 2016, 130 trees were planted but only 65 survived. The 85 trees that dried up was mainly due to lack of adequate water. The water used is usually from River Tiva, which is seasonal and hence dries up during dry seasons. However, she has recently started harvesting road water, although the water has not started being used for irrigation. The tree species planted are *Melia volkensii*, Neem tree and *Casuarina equisetifolia*. The latter is a fodder tree which she uses to feed her livestock. She has also planted maize. It is planted in the same ditch as the trees and this ensures that the maize crop has adequate shade. The maize have had about a 30% increase in yields because of agroforestry. The trees do well in intercropping systems because when you weed the crops, you are also weeding the trees. When the goats feed on the seeds of the trees, the seeds are distributed through the goat droppings and hence more trees grow in the farm.

Last December, Mrs. Diana started practicing road water harvesting. A cutoff, retention ditch and farm ponds were dug. Once the road runoff fills the retention ditch, it is pumped to the first farm pond and once it is full, the water is then pumped to the second farm pond. Since the ponds were dug recently, they have not started using this water for irrigation.

She has also planted pumpkins on the side of the ponds. She is also planning to plant pigeon peas and cabbage. The farm pond was dug with the help of Mrs. Diana's son who has studied water harvesting. She expects that the RRH will result to increases in crop yields.

Figure 9: Retention ditch, where the road runoff is first stored

Figure 10: Farm pond, where the water is pumped to once the ditch is filled

Farm as a result of gully rehabilitation

This farm was as a result of gully rehabilitation. Water is harvested from the road and it is diverted to the farm using well-constructed farm trenches. The water is then stored in a farm pond that is well-constructed and lined by a material that reduces evaporation and keeps away mosquitoes. The water is conveyed to the plants by the use of a pipe that conveys the water to individual plants. On the farm there is a lot of crops including coriander (*dania*), kales and tomatoes. Due to this water harvesting system, the farmer has sold a lot of tomatoes. There is also a tree nursery that has *Moringa oleifera* trees. There is an overall increase in yields of the food crops by about 50%.

3. Practices in Machakos County

Machakos, particularly Miu location, Muthetheni ward was chosen as an area of study due to the spread of RRH practices, especially for the farms in proximity to the road or paths. Five farms were visited where RRH is being practiced in Muthetheni ward. The visits were accompanied by David Mutua, an agricultural extension officer who worked in association with MetaMeta to train farmers on RRH. Some of the farmers had seen the opportunities for RRH and were even practicing it. The training happened nine months ago and it has helped farmers to harvest road water. Mr. Mutua has personally trained more than 40 farmers in this area, who now practice RRH. The farmers then formed a group known as Miu Fruit Farmers, so as to have easy access to knowledge, skills and resources for RRH. This initiative has helped a lot of farmers in this area to harvest water into their farms.

Farm of Mr. David Mutua

This farm is owned by Mr. Mutua. There are terraces, which were dug to divert and store road runoff in the farm. The water used to flow down to the river and now the water is stored in the farm. Since the previous rains were 730 mm per season instead of the usual 350 mm per season, the road water harvesting led to abundant water supply to crops and trees and storage in the soil profile. The farm has pigeon peas and mango trees that are doing very well due to RRH. Napier grass has also been planted as a supplementary source of feed to the animals.

The previous owner of the farm because it was unproductive. However, now due to RRH and agroforestry it is very productive. Mr. Mutua

Figure 11: Channels constructed for conveying road runoff into the farm pond

Figure 12: Farm pond for storing road runoff for supplemental irrigation

Figure 13: A cutoff drain that diverts road runoff into a retention ditch in Mr. Mutua's farm

expects that within seven years, he will get 750 fruits from one mango tree. This is because of the RRH supplies enough water to the fruit trees. The RRH structures in the farm are; a cutoff to divert road water, a retention ditch to store the runoff and terraces in the farm to convey water to the pigeon peas and the mango trees. There has been approximately a 40% increase in agricultural yields. This is because before the RRH, the farm was barren and it didn't have any produce. But because of RRH there are pigeon peas and mango trees that are doing well.

We also met Emma who owns the adjacent farm. She said that that RRH has helped the farmers in the area, especially for her, since she has terraces that convey water to her farm. Mr. Mutua's advice to Emma was to cut down the Napier grass in her farm and feed her animals. This is because if the grass grows more than it has, there will be a lot of fibre and hence its nutritive value will go down.

Farm of Mrs. Eunice Peter

The road runoff used to flow to the river, however, due to RRH the water is now being diverted into the farm, where it is used effectively. The MetaMeta team advised the farmers to harvest water from the road since it was an unused potential. The crops planted are pigeon peas, bananas and pawpaw and fruit trees e.g. mango trees. Though RRH has helped this farmer there is still work to be done. This is because a retention ditch has not been dug and therefore a lot of sand from the road is being carried into the farm by the road water and therefore causing siltation. Since RRH the agricultural yields have increased by about 10%. But due to lack of a retention ditch the farm accumulates sand soil and hence the farm is still not very productive.

Farm of a neighbor to Mrs. Eunice

In this farm, a retention ditch has been dug to store water and to also ensure that the sand is deposited there instead of going into the farm. The farmer has also dug terraces in the farm to convey the road runoff. The crops grown are; bananas, maize and pigeon peas and fruit trees that include mango and pawpaw trees. She has seen change in production since she started practicing RRH. She has harvested more maize than before since she started harvesting road water and pigeon pea production has also been more and hence the agricultural yields have increased by approximately 30%. The mango trees have also started flowering.

Figure 14: A cutoff drain that divert and convey road runoff into Mrs. Eunice's farm

Figure 15: A cutoff drain, retention ditch and terrace to convey road runoff in the farm

Water used to flow down to the river before and now due to RRH the water is utilized effectively. When it rains and the retention ditch fills with water she closes the cutoff using a sack filled with sand so as to allow the water to flow down to the other farms.

Farm of Mr. Martin Njue

Mr. Njue has dug a retention ditch and terraces that convey water to the crops and fruit trees and since RRH the mango trees are getting more water. According to Rose Njue, Martin's wife, the main challenge they faced was water shortage, but because of RRH there is enough water for the crops and fruit trees. In the previous season they harvested 10 sacks of maize and 2 sacks of beans, which was an increase in yields by about 25%.

The crops grown are pigeon peas, maize, beans, yams and pumpkins and fruit trees mainly grown are mango and orange trees. He has also has Napier grass for his animals. During the previous March to April rains, which were 730 mm per season instead of 350 mm, there was a lot of water flowing into the farm and hence he dug a ditch that retained water in the farm. This was done within the first three months after the training. There has been a difference in yields since they started practicing RRH and maize has been adequate. Last year's December rains were inadequate with 160 mm per season instead of 350 mm and led to drying up of some of the pigeon peas. The ones that remained are now doing a lot better, producing better yields. It is also expects that the mangoes will have higher yields this season due to RRH.

The deposition of excess sand in the farm was also another factor that led to the digging of the retention ditch, so that the sand is deposited there instead. The sand is then collected by use of a wheelbarrow and is used to the repair the house. The retention ditch reduces siltation because

Figure 16: A retention ditch for storing water and excess sand

it accumulate the excess sand. The farm has only one terrace and according to Mr. Njue, it is enough for storing water for the entire farm, though he plans to dig another terrace on the lower section of his farm for planting more Napier grass. Since the digging of the retention ditch, the water is being controlled and therefore it is not flooding the farm and destroying the crops. David Mutua emphasized that it is important for the farmers to know that the water is not an enemy.

Absent Farmer

This farm has a retention ditch and three terraces for conveying road runoff to crops and trees. The crops grown are; pigeon peas, bananas, mango trees and Napier grass. It is the pioneer farm in the area to practice RRH after the training. Before the retention ditch was dug in the farm, water used to flow into the farm and this caused water logging. During this time the farmer wanted to grow mangoes but the soil was water logged and the crops in the farm were also poor.

After the terraces were dug, bananas were planted in the terraces. The farmer has harvested twice since the training. The road water flows through the first terrace and once it gets filled, the water continues to the next terrace through a path on the side of the farm, and once the second terrace is filled, it flows to the third terrace. Since RRH the pigeon peas are doing very well.

Grevillea robusta trees have been planted on the side of the farm. Mr. Mutua advice to this particular farmer is to plant the grevillea trees in the farm. This is because they help in soil water retention, provide timber and provide fodder for the animals. In his other farm, has 30 grevillea trees and he produces the best maize in the area.

Figure 17: Retention ditch and terrace for conveying road runoff into the farm

Before the farmer started practicing RRH, there was poor pasture and the crops looked very poor. The farmer thought it was a matter of soil fertility, but with the help of David Mutua and the MetaMeta team, they discovered it was a matter of water management. Since RRH, the farmer has seen increases in production of pigeon peas and mango trees by about 40%.

The Napier grass has been planted on the side of the terraces. This is so that the soil can be utilized and also for soil stability to prevent the soil form falling back into the terraces. The Napier grass is used to feed the animals.

4. Impacts of RRH systems

The following is a summary of impacts of RRH systems reported by farmers in Kitui County.

Table 1: Summary of impacts of RRH systems in Kitui[1]

Name farmer	Impacts of RRH systems
Mr. Geoffrey Musyoka	There have been an increase in yields of cow peas and pumpkins by approximately 30%. The bananas and paw paws have not yet been harvested and therefore the increase cannot be estimated.
Mrs. Rose Mlaa	The section of the farm with trees, 25% more pigeon peas were harvested compared to the section with no trees.
Mr. Priscah Mutia	On the lower section of the farm where maize is intercropped with mango and orange trees, the yields have been more by about 20% in comparison with the upper part where there is no intercropping.
Mrs. Diana	Since she started practicing agroforestry in 2014, she has seen her yields increase by about 30%.
Farmer in Kwa Vonza	Gully rehabilitation coupled with agroforestry and RRH has made the overall yields of the farm to increase by approximately 50%.

1. *The values indicated in table 1 above are estimates based on the information gathered from the farmers during the interviews. Poor record keeping by the farmers led to estimation of the percentages of the increase in yields in Kitui. Therefore, further research is required in order clearly determine the impacts of agroforestry on agricultural yields.*

The following is a summary of impacts of RRH systems reported by farmers in Machakos County.

Table 2: Summary of impacts of RRH systems in Machakos[2]

Name farmer	Impacts of RRH systems
Mr. David Mutua	There is a 40% increase in agricultural yields. This is because before the RRH, the farm was barren and it didn't have any produce. But because of RRH there are pigeon peas and mango trees that are doing well.
Mrs. Eunice Peter	Since RRH the agricultural yields have increased by about 10%. But due to lack of a retention ditch the farm accumulates sand soil and hence the farm is still not very productive.
Mrs. Eunice's Neighbour	The agricultural yields have increased by approximately 30%. The farmer has harvested more maize than ever before as a result of RRH.
Mr. Martin Njue	Before RRH ½ sack of beans used to be harvested but now he harvests 2 sacks of beans. Therefore there is a 25% increase in the yields of beans. 2 bags of maize were harvested before RRH, but now he harvests 10 sacks of maize per season. Hence there is a 20% increase in yields of maize.
Absent farmer	Before the RRH, the farm was very unproductive and the soils were waterlogged. Since RRH, the farmer has seen increases in production of Napier grass, mango trees and pigeon peas by about 40%.

The results of this research show that road runoff harvesting has increased agricultural productivity and agro-ecosystem sustainability in the areas that were visited, and therefore if these practices can be incorporated in other areas, the agricultural productivity of the other areas could also increase. The agricultural productivity has been increased through increase in yields and reduced soil erosion has increased agro-ecosystem sustainability. Some of the farmers mostly those in Machakos have planted Napier grass as a supplementary source of fodder to livestock. The Napier planted on the embankment of the terrace has stabilized the soil and prevented the soil from falling back in the terrace.

The initiative by MetaMeta, with the help of David Mutua has been very helpful in bringing resources, knowledge and innovation to farmers in Machakos on RRH. As seen in most of these systems, a retention ditch is vital. This is because the water is controlled and therefore there is no flooding of the farm and this prevents waterlogging of the soil. As discussed in last farm visit in Machakos waterlogging caused poor yields of pigeon peas and low quality Napier grass. The terraces also have to be properly measured, by agricultural experts, so as to effectively convey and store the runoff.

Road runoff harvesting has also been beneficial to the fruit trees planted in the farms. Fruit trees like mango and pawpaw trees that require a sufficient amount of water can utilize the road water and hence produce more fruits for consumption and sale. The sale of the fruits results in additional income to the farmer.

If the runoff is stored in a farm pond seen in Kitui, then it has to be properly lined so as to prevent water loss by infiltration. Mr. Mutia's farm pond in Kitui lacked lining and hence it had no water stored from the previous rains. However in Mrs. Diana's farm due to proper lining of the pond, there was water stored from the previous rains.

According to Mr. Mutua, this innovation of RRH will make the government spend less money to repair the roads and the farmers will benefit from the water. Less money will be spent to repair the roads because the water that damages the roads during the rains will be utilized in the farmland for agricultural production. The farmers have the most to benefit out of this because they will have sufficient water for agricultural production and hence increased yields. As seen from the farms visited, especially in Machakos, where RRH is dominant, harvesting of road water has immense benefits to the farmer and to the environment.

The values in table 2 above are not based on exact values given by the farmers. However, they are based on information given by the farmers during the interviews conducted. Poor record keeping by the farmers on their previous harvests necessitated the estimation of the percentages in the table above. Moreover, the findings were inconclusive but present optimistic benefits and hence further research is required to assess impacts of RRH in relation to increasing yields.

Figure 18: Farm without road runoff harvesting

Figure 19: Farm with road runoff harvesting

The farms that have RRH structures are different from those that do not have because of availability of water for crop production. Road water harvesting ensures availability of water in the farm even after the rains. The farms that have RRH also appear to look greener and hence more productive than those that do not. The farm in Machakos where the farmer was absent appeared greener compared to Mrs. Rose Mlaa's farm where there was no RRH.

5. Impacts of integration of Agroforestry

Agroforestry was mainly practiced in Kitui. Mr. Musyoka has seen a great improvement in the productivity of pumpkins, pigeon peas and bananas. The *Melia volkensii* and Neem trees, which are found in his the farm, have proved to have positive effects in the production of pumpkins and pigeon peas. When these trees were intercropped with maize, they had negative effects on the maize, in that the maize had stunted growth.

Trees on farms also have a lot of economic benefits to the farmers through sale of timber that has results in increase of income. Mr. Geoffrey Musyoka sells the timber of the *Melia volkensii* tree, which is strong and durable, and it increases his source of income. Fodder trees e.g. *Casuarina equisetifolia* and *Grevillea robusta*, have also provide fodder for the livestock. Mrs. Diana in Kitui, has *Casuarina equisetifolia* which has been beneficial in providing a feed for her goats. All the farms that were visited did not have *Grevillea robusta* trees intercropped with the crops. Grevillea trees have immense benefits to the crops and the environment. They help in soil water retention, provide timber and provide fodder for the animals. Therefore these trees should be planted by the farmers under agroforestry systems. Fodder trees can be used as a supplement or as a substitute for concentrate, thereby saving the money that could be used for buying concentrate. Trees also have aesthetic value since they beautify the farm, as stated by Mrs. Rose Mlaa, a farmer in Kitui.

Mr. Mutia, who practices RRH and agroforestry in Kitui, has had increase in production of maize. On the upper part of the farm he has planted Melia and Neem trees, though has not intercropped with crops. On the lower section of the farm, he has planted mango, oranges, pawpaw trees and maize. The increase in production has been mainly due to availability of water due to RRH. He harvests the road water and stores it in a farm pond and once it's filled the water moves through a terrace to the lower section of the farm, where it benefits the fruit trees.

Trees can be planted in the same hole as the maize, as seen in Mrs. Diana's farm. The maize are intercropped with Melia and Neem trees. The maize are able to get shade from the trees and the trees benefit such that during weeding of the maize, the trees benefit from the weeding too. There have been increase in maize production due to agroforestry. Especially for the trees planted in 2016 that were not eaten by goats because she had fenced her farm. Most of the trees that had been planted in 2014 and 2015 had been eaten by goats and this led to fencing of the farm.

The main challenge that the farmers have encountered in Kitui is the trees being eaten by goats. The goats mainly feed on the young trees and this is due to lack of fencing. Some of the farmers e.g. Mrs. Rose Mlaa and Mr. Mutia have fenced their farms so as to curb this problem.

6. Benefits of Road Runoff Harvesting

The farmers that practice RRH in Kitui and Machakos harvest the water directly from the road or path. It is done for smallholder farmers and it has shown to be very effective because the water is utilized effectively instead of flooding the farm. The farmers have stated that they have seen an increase in agricultural yields especially in pigeon peas and mango trees that are commonly cultivated in both Machakos and Kitui. RRH prevents waterlogging of the farm by road runoff.

A retention ditch is an important structure in the RRH system. This is because it collects excess sand that can be used to repair houses. Siltation is reduced due to the accumulation of the sand in the retention ditch. It also controls the water that is getting into the farm. This then prevents waterlogging of the farm that can reduce agricultural yields.

Road water harvesting prevents road damage, in that the water that damages the roads is instead utilized in the farms. The water harvesting will reduce the money being spent by the government to repair the roads because the water that damages the roads during the rains will be utilized in the farms. When more farmers take up this innovation of RRH, other farmers will see the positive effects it has on farm productivity and this will in turn motivate other farmers to also practice it. This will ensure that RRH can upscale fast.

7. Additional benefits of agroforestry

Agroforestry is also practiced in these areas. The trees commonly grown in Kitui are *Melia volkensii* and Neem trees. This is because the seeds are provided to farmers through the Forest Market Foundation. This foundation was formed by farmers so that they can get easy access to seedlings. These trees survive in these areas because they are drought resistant. Agroforestry has also proven to increase the production of crops, particularly in Kitui, Kathome sub-location. In the sections of the farm where there are trees, production of maize and pigeon peas has also increased, as seen in Kawongo sub-location, Kitui.

The farmers who practice both RRH and agroforestry have even better yields because there is abundance of water in the farm and the trees help in soil water retention for instance, the fodder trees e.g. *Grevillea robusta*, as seen in Machakos and *Casuarina equisetifolia*, as seen in Kitui that provide feed for the animals. These fodder trees are either used as a supplement or as a substitute for concentrate, thereby saving money for the farmer.

Therefore the integration of agroforestry in RRH should be encouraged in the ASALs of Kenya. This is mainly because the ASALs constitute about 80 percent of Kenya's land and water scarcity is a problem in these areas due to the severe droughts. The ASALs constitute majority of the country's area and there is an unused potential in harvesting of road water during floods and diverting the water into the agricultural fields.

8. Scalability of Road Runoff Harvesting

There is a potential for scaling up RRH in Kenya and SSA. This is because the ASALs constitute about 80 percent of Kenya's land. Because of this there is an opportunity for farmers in these areas to harvest road runoff in times of rains for agricultural production. The farmers visited especially in Kitui where there was not much RH did not have enough water for agriculture. The water that was used was from a seasonal river known as, River Tiva whose water was salty and wasn't enough especially in the dry season. There lies an opportunity for up-scaling RRH in the area. Since the previous rains were 730mm per season instead of 350mm, there was a huge opportunity for farmers to harvest the water. Those that harvested in Machakos had plenty of water supply for crops as opposed to those that did not.

Scalability of RRH calls for collaboration, networking and partnership among local farmers and stakeholders in research, the government and development partners. As seen in Machakos after the training held by the MetaMeta team on RRH some of the farmers took up the practice. This encouraged even more farmers to practice RRH when they saw the increase in yields of the pioneer farms. In Muthetheni ward, Machakos County there are more than forty farmers that practice RRH because of the training that took place.

Finally, RRH is a triple win situation in that; it reduces the cost required for road maintenance, because there is reduced damage from roads through flooding and erosion, water is managed for productive use and there is an increase in soil moisture and water retention, and hence increase in yields.

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Experiences with Road Runoff Harvesting and Agroforestry

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This practical note has been prepared by Joyce Njuguna. This research was conducted during her attachment at The World Agroforestry Centre (ICRAF) and the Flood-Based Livelihoods Network (FBLN) as part of her BSc undergraduate attachment research at the University of Nairobi.

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