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RUFORUM Case Studies

The Impact of Graduate Research Grants: Examples from Botswana

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When enterprising farmer Eric Galotshoge had the idea of importing a herd of dairy goats and producing goats' milk to satisfy a burgeoning local market, he thought he was onto a sure thing. As a farmer with an entrepreneurial turn of mind, he did his market research and found that a strong demand existed from local supermarkets, hotels and game lodges for locally produced goats' milk.

What he did not anticipate, however, was the difficulty of feeding and caring for his herd of 30 British Alpine and Toggenburg goats, imported from South Africa. These highly productive – and somewhat high-maintenance – dairy animals could not simply be left to forage off the land, as the local Tswana goats typically do. They needed to eat lucerne (a forage crop known also as alfalfa), which was not readily available in Botswana. "*These exotic breeds didn't acclimatise well, and all 30 goats died because of disease and lack of feed*," he says.

At the time, Galotshoge was gearing up to collaborate with university researchers who were planning to do experiments on his farm in the hope of discovering how best these highly productive dairy goats, imported from temperate climates, could be helped to thrive in Botswana's arid climate, particularly as a poverty-alleviation measure for small farmers with few resources. But most of Galotshoge's goats died before work could begin, due ironically to the very lack of knowledge that researchers were hoping to gain through their on-farm experiments. As an intrepid farmer with resources and business acumen, Galotshoge had as good a chance as most farmers do of capitalising on a promising new idea. But because of critical gaps in his knowledge that could only be supplied by local research, the enterprise failed on his first attempt.

Fortunately, Galotshoge is trying again – and this time he's collaborating with researchers from the Botswana College of Agriculture, who have been involved in research to support dairy goat farming among small-scale farmers. Touring his farm with Dr Gaolebale Mpapho, a senior lecturer in dairy science, Galotshoge points out facilities that he has designed specifically with small-scale farmers' needs in mind, such as a small elevated shelter and a milking platform.

The dairy goat initiative is one of three projects from the Botswana College of Agriculture that is being supported by the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), a consortium of 45 African universities in 22 different countries, through its Competitive Research Grants programme to support masters-level training.

All the projects have filled important gaps in the university's research agenda. The Botswana government has identified agriculture as a crucial sector for diversifying the country's mineral-based economy. More than 80% of Botswana's population relies on agriculture, yet farming is tough in the semi-arid conditions that prevail here, and production falls short of meeting the country's food needs. The three competitive research grants from RUFORUM have helped to build capacity in the critical areas of **dairy goat farming**, **rainwater harvesting**, and **safe urban agriculture**.

The **dairy goat project** forms part of a broader initiative of the Botswana government to introduce dairy goats as a poverty-alleviation measure, and has focused on cross-breeding hardy local Tswana goats with highly productive imported breeds such as the Saanen and the British Alpine, in order to develop breeding stock that is well adapted to local conditions and also produces ample milk, says Dr Mpapho, the project's principal investigator.

From the research proposal: "*Statistics show that the majority of households in Botswana are female headed. Therefore, this research project will thoroughly investigate production, nutrition, reproduction and health requirements of dairy goats in small-scale farms of Botswana with the aim of increasing milk productivity of goats. Through participatory action research, knowledge generation will be strengthened. Development and improvement of their productivity will offer the most significant and direct positive impact for improved family protein and energy intake, family income as well as improved standard of living of the resource-poor farmers. Milk and milk products if sufficiently available could efficiently correct nutrient deficiencies or be part of most African diets.*"

According to the project proposal, Botswana's National Development Plan of 2003 emphasises that "*the greatest challenge facing smallholder farmers in Botswana at present is to increase milk production, reduce milk imports and by so doing, improve food security and rural employment and incomes. Recent speeches by the Minister of Agriculture indicate that low milk production is a result of limited knowledge of dairy production systems.*"

Referring to the imported dairy goat breeds, Dr Mpapho's colleague, Prof. Shalaulani James Nsoso, head of the Department of Animal Science at the College, explains: "*These are very fragile animals: if you look after them, they look after you. But they need 5-star hotel treatment.*"

"The goat is a very important animal here in Botswana. Because of its size and the general social context in which the goats are bred, especially by women, it has the potential to fill an important niche."

Prof. James Kamau

A major objective of the study has been to build the linkages between the university and farmers through participatory research. "*We're trying to move towards applied research with farmers*," Prof. Nsoso explains. "*We're working with farmers under their own conditions. Nothing is more convincing to a farmer than seeing his neighbour doing something that is working*."

In the dairy goat farming study, the two masters students sponsored by RUFORUM both focused on aspects of harnessing goat production to meet food and nutrition security challenges and at the same time boost the incomes of small-scale farmers. One of the students, Keleaboga Dipheko, studied the opportunities and constraints in the production process, and compared the efficacy of different types of feed, looking specifically at whether costly imported lucerne might be substituted with a local protein-rich crop called lablab.

The other student surveyed small-scale farmers across the area who kept goats, with a view to helping them to build small-scale agribusiness and value chains. Travelling the countryside on a battered old motorbike and keeping tabs on some 60 farmers producing goats' milk on a small scale, the student mapped the informal value chain – tracking milk from the source of production to consumption – and was able to look at what other inputs came into the system: the types of feed that farmers used, for example, and their access to veterinary medicine. Along the way, the university partnered with the Botswana Bureau of Standards to measure concentrations of somatic cells indicating the levels of mastitis in the milk. Mastitis is a bacteria that infects the teat, causing red and painful swelling and disrupting the chemistry of the milk by destroying the calcium and other nutrients. Interestingly, the study found low levels of mastitis among the small farmers' milk production, a further indication that a small-scale goats' milk industry may be viable.

Dipheko, who worked on his masters in animal science and management systems between September 2011 and October 2013, focused on comparing the advantages of lucerne as a feed compared with the locally abundant, protein-rich legume crop lablab (*Lablab purpureus*, sometimes known as the hyacinth bean). His research findings indicated that the nutrients in lucerne are more easily absorbed by the goats than the nutrients in lablab. "*I was interested in the demographic and socio-economic profiles of farmers, the types of goats they kept and their management and production systems: what types of feed were available, and whether they were providing shelter for their goats*," he explains. In his research, he visited twelve farms located in three different rural districts, where farmers kept ten goats on average.

Dipheko also collected data from a herd of Saanen goats kept at the university's farm, and gained hands-on experience in milking them and tending to their needs. "*If Botswana College of Agriculture does not hire me, I will become a goat farmer and raise dairy goats myself, so that farmers can see someone who is professional about raising goats*," he says.

"*The goat is a very important animal here in Botswana,*" says Prof. James Kamau, an animal scientist whose expertise in heat stress

Dr Gaolebale Mpapho demonstrates how the goats' milk is tested for mastitis at the College.

Masters student Keleaboga Dipheko gained hands-on experience looking after the College's herd of Saanen goats.

was an asset to the project. "*Because of its size and the general social context in which the goats are bred, especially by women, it has the potential to fill an important niche, but there is the question of elevating it to a commercial level. People have always raised Tswana goats and are good at that, but now we must see if they can meet the challenges of keeping these highly productive animals.*"

In the results that have emerged so far from the RUFORUM-sponsored research into dairy goat farming, Prof. Kamau explains: "*It stands out that people can produce hygienic milk at the lowest level*" without the same emphasis on industrial processes and equipment that accompanies large-scale production. "*The problem comes in when you start moving this milk along a value chain, and it gets contaminated along the way.*"

He continues: "*There is milk out there, and it moves around in a local economy that cannot be described. In every home, they make white tea, and it comes from the milk of these animals. It doesn't appear as commerce as such – the purpose of keeping these animals is to enhance family health.*"

This statement illustrates the multiple potential benefits of developing a small-scale industry out of goats' milk production. For one thing, goats have many advantages for resource-poor farmers: they are far more affordable than cattle; require very little land and food; reproduce quickly and breed at a younger age; have multiple births; are generally able to feed on a wide range of forages; and are easily handled by women and children. If families can produce milk to enhance their own nutritional status, and on top of this sell off a surplus to a ready market, they will earn extra income, which can be spent on educating their children and other household needs – while, at the same time, urban consumers gain access to a high quality, affordable source of protein and nutrition. In other words, dairy goat farming is important in terms of building small and medium-scale agribusiness, while boosting nutrition security.

The production systems for goats are far less capital intensive and technically demanding than for cows, providing yet another reason why they make more sense for the rural poor. And goats' milk is richer and higher in certain nutrients than cows' milk.

As already mentioned, the dairy goat project involved introducing foreign breeds, primarily the Saanen and Alpine goats, for cross-breeding with indigenous goats, to boost milk production. But while Botswana farmers are accustomed to keeping goats and other small livestock, the dairy goats are not only costlier animals, costing nearly US$300 apiece but – as farmer Galotshoge found with his 30 imported goats – are far higher maintenance than indigenous breeds, requiring farmers to improve their management techniques in order to protect their investments. The imported goats tend to be more susceptible to disease, and customary practices of allowing goats to forage on their own on thorny acacia branches will not do, as the goats require a diet of high quality grains to optimise their milk production, and might damage an udder while roaming amidst thorny trees. They must also be kept and milked in sanitary conditions to reduce the risk of infections such as mastitis.

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Botswana currently imports about 80% of its milk supply, but at the same time the country has done little to harness the ubiquitous livestock resources in its own 'backyard' to satisfy the growing demand for milk. The reliance on imports siphons cash out of the local economy, and at the same time makes a valuable source of nutrition too expensive for vulnerable populations, particularly the extraordinarily high percentage of the population that suffers from HIV/AIDS. Thus the development of a proper dairy goat industry has enormous potential for generating wealth and boosting food and nutrition security, especially among the poor and vulnerable.

The College of Agriculture plays an important role in building an evidence base upon which a viable industry can be built. By examining questions ranging from optimal breeding patterns, to disease control, heat stress, and feed analysis, university research has been setting the stage for the dairy goat industry to grow. The project has also helped to build collaboration, partnership and linkages with farmers and government, says principal investigator Mpapho. In particular, the project has served as a way of building the participatory linkages with farmers that were missing in the past and are crucial to producing research that is relevant and can be channelled towards building viable industries.

Studies from Malawi and Zimbabwe have shown that intensive farming management systems and practices, developed through scientific research, are critical for farming success, particularly with regard to issues such as identifying quality feed and ensuring the health of livestock.

As Africa's shift towards urbanisation opens up new market opportunities for poor, small-scale goat farmers, the trend has also introduced new challenges in areas of urban food production and water management. Pressures are intensifying on farmers to produce more food to feed growing urban populations, with fewer land and water resources available.

Lablab is a locally cultivated legume that has the potential to replace costly imported animal feeds.

"We're working with farmers under their own conditions. Nothing is more convincing to a farmer than seeing his neighbour doing something that is working."

Prof. Shalaulani James Nsoso

Another RUFORUM-sponsored competitive research grant at the Botswana College of Agriculture has supported **research into optimising rainwater-harvesting techniques** used by Botswana farmers. Farmers have long used a variety of methods to capture and store water to irrigate their crops, but the project employed the precision of engineering and science to help farmers further develop their techniques and gain more from the water resources they are able to capture.

"*It's all about capturing and storing water runoff as it comes*," says Wright Baipusi, a RUFORUM-sponsored masters student who completed his research in agricultural engineering in soil and water management.

Driving out to visit a community of small farmers he is working with in the town of Mochudi, about 60 km from Gaborone, Baipusi explains some of the water stresses that the area is facing. While the country's water supply situation has always been tenuous, with highly variable rainfall, and with droughts being endemic, the patterns are increasingly variable: the Gaborone Dam is only 17% full, and city residents endure water cuts several days a week. Increasingly, with climate change, water is often scarcest at the times when it is most needed. Farmers have long adapted rainwater-harvesting practices to optimise their water usage, but in some parts rainfall is as low as 250 mm per annum.

The competitive research grant project answered a need to bring science to bear on these problems – to harness knowledge of soil structures, for example, to ensure maximum retention of water in the soil, and healthy plant growth. When it is not managed well and its life-sustaining properties are not harnessed, rainwater becomes a destructive force, with the runoff causing erosion, flooding and siltation.

The project sought to show that the optimisation of rainwater harvesting would make farming a viable prospect in bad rainfall years and good ones alike. It had three main components: characterising the soil surface conditions in rainwater-harvesting catchment areas constructed by farmers; appraising whether rainwater-harvesting techniques had any impact on the growth and performance of crops; and assessing the socio-economic potential of rainwater-harvesting systems in a particularly arid sub-district called Bobwira.

"*Water is the limiting factor in the cultivation of food crops*," explains Prof. Benedict Kayombo, the principal investigator on the project, arguing that it is thus crucial that farmers ensure "*the efficient use of scarce rainwater that is available*".

Participatory research methods featured heavily in the project, as researchers worked with farmers to ascertain current rainwater-harvesting practices and figure out what sorts of collection systems would be viable within communities. Many farmers were already collecting rainwater to feed small gardens. The researchers and students enlisted farmers who were enthusiastic about the concept, to employ more systematic approaches of building catchment areas and channelling the water to fields, where they could observe whether it could be tapped for maize production, and record their progress – with periodic visits by researchers to collect data and take measurements of plant growth and biomass, and deal with other factors as they arose, such as crop pests.

Many of the techniques explored in the project were simple: farmers, for example, can build strategically placed dikes, ridges and furrows to capture rainwater in their crop areas – this way, the soil itself becomes a reservoir, and the stored water irrigates the crops. The size of the catchment area also has bearing upon the type of crop that can be grown: whether trees, grain crops, or annual crops planted in rows.

The researchers used a basic equation in the design of the rainwater-harvesting systems, to optimise the design of a system based on such variables as the topography of the area; the characteristics of the soil, including its depth, texture, water-retention capacity, infiltration characteristics and hydraulic conductivity; climate conditions, including rainfall, evaporation and transpiration; and crop characteristics such as root depths, growing season, critical stages of growth, and plant spacing.

For his research, Baipusi studied the interactions between the surface conditions and the catchment sizes of the farmers' experimental plots – looking, for example, at what effect was produced if the land was ploughed or unploughed, furrowed, or covered in natural vegetation.

"*We realised that from the ploughed surface, we had more moisture at the end of the season than from any other surface*," he says. "*If you harvest water and retain it in a ploughed surface, it will retain the moisture and give you a higher growth rate for that season...We realised that most farmers have uncultivated areas where significant runoff can be generated. Farmers can direct the water to a small cropped area where harvested water can be used to increase crop yields on their land.*"

Even small catchment areas of as little as 5 square metres, if they have a regular slope, and perhaps are also aided by the use of ridging and channelling techniques, can hold a significant amount of water, which is then less likely to evaporate than if the water is spread out over a larger catchment area, Baipusi adds.

As Kayombo explains: "*If there is extra water to be generated for crop growth, most likely it would be directed to a maize field or a horticultural crop like cabbage or vegetables that have a higher value...If farmers can manage to harvest a bit more water than nature can provide – where they were expecting to get maybe 40 mm of rainfall, and if you harvest an extra 40 mm and have 80 mm to use on a crop – that's an adaptation measure, and the crop is more likely to survive.*"

Once the key principles are understood, the technology is inexpensive and easy for farmers to adopt, requiring them to perhaps construct a ridge around an uncultivated plot to help channel the water – but little more.

After completing his masters, Baipusi was awarded a Field Attachment Programme Award (FAPA) grant from RUFORUM in order to disseminate his research findings to farmers. Through the project, linkages have been built with the Ministry of Agriculture, and

Masters student Wright Baipusi is working with this group of farmers on rainwater-harvesting techniques.

farmers' associations and extension workers have also learned about the benefits of rainwater harvesting. In future, Kayombo hopes to build on the project and introduce conservation agricultural techniques as a further simple and low-cost measure to help farmers make the most of rainfall. "*The concept we would like to extend is that instead of having large water catchment areas, you can store the water right there in the soil where it is utilised by the crop. Then you can use conservation agriculture, with no tillage, or with minimal tillage, to further conserve moisture in the soil. That is the link*."

The third competitive research grant to the Botswana College of Agriculture also has wider relevance. As the continent is urbanising rapidly, millions of poor, unskilled migrants to cities are practising urban and peri-urban agriculture, to meet their nutrition needs and also in the absence of other work opportunities. These urban producers play an important role in supplying fruit and vegetables to expanding cities, but their input-intensive practices can also contaminate soil and groundwater, as well as the food they produce.

This third project also used participatory action research, **working with local urban farmers** to develop techniques to ensure sustainable management practices to protect the soil and water, as well as the quality of the produce, in urban farming. Urban farming practices often tend to be characterised by heavy input use, including chemical fertilisers, pesticides, wastewater and industrial effluent, which sometimes contains hazardous materials. The project was designed to apply a nutrient-balance approach to urban and peri-urban farming systems around Gaborone, and involved quantifying the inflows and outflows of nutrients in these production systems in order to reduce both nutrient loss and contamination.

The UNDP has estimated that some 800 million people globally practise urban and peri-urban agriculture; and, according to the UN's Food and Agriculture Organization (FAO), urban farmers produce nearly a quarter of the world's food supply. Urban farmers in Gaborone, like in most other cities, draw heavily on sewage water, inorganic fertilisers, pesticides and organic wastes. Heavy reliance on wastewater, for example, raises the risk of industrial effluent, pathogens from untreated wastewater, heavy metals, and other hazardous substances contaminating the soil and the produce. Once again, the scarcity of water in Botswana makes the usual problems of using marginal and contaminated water for irrigation even worse, as practices such as recycling sewage water are commonplace, says Thembeka Mpuisang, a lecturer in irrigation engineering who participated in the project as a masters supervisor.

The objectives of the project were to help farmers optimise the use of inputs, while reducing nutrient-leaching losses – at the same time ensuring food safety and soil health as well as the sustainability of urban farming systems. The project is also expected to generate scientific data on food and vegetable safety from urban agricultural systems, and to help inform both policies and practices concerning urban agriculture.

Specifically, the study sought to address several hypotheses: firstly, that high nitrogen input usage contributes to nitrate-nitrogen leaching into groundwater as well as greenhouse gas emissions; secondly, that significant reductions (of up to 50%) in nitrogen inputs would not affect the productivity of urban farming systems; and thirdly, that current farming practices contribute to high risks of heavy metal contamination in soil, food and vegetables – in accordance with scientific findings internationally that vegetables are the leading source of human consumption of heavy metals.

Correspondingly, the objectives of the study were to quantify NPK (nitrogen, potassium and phosphorus) losses and nitrous leaching into groundwater; assess gaseous emissions of nitrous oxide, ammonia, carbon dioxide and methane from urban gardens; determine the extent to which nitrogen could be reduced as an input, without reducing productivity; and determine the effect of existing soil management practices on the accumulation of potentially toxic metals in food and soil.

One of the two RUFORUM-sponsored masters students on the study analysed the nitrate leaching and gaseous emissions in production and land-use systems; the other assessed the levels and causes of build-up of toxic metals in urban farming systems.

The research, supervised by lecturer Mpuisang, employed several testing and sampling methods: for example, using moisture detectors planted at different depths in the soil to measure how deeply the water penetrates the soil, and then analysing the soil at these different depths. As part of the experiment, farmers used different levels of inputs in different areas, so that these nutrient levels could be compared as well. They also tested the water for salinity, another crucial measurement, as farmers are often unaware of the build-up of salinity over time, which if not handled properly will ultimately render the land unfit for farming.

"*Farmers add so much fertiliser, which is a cost for them and also pollutes the underground water and the soil*," says Mpuisang. "*To practise good horticulture, you must continuously monitor the nutrient levels, especially the nitrogen*."

"*I like working with farmers*," she says. "*You learn so much from them, and they've been doing this for such a long time, they have reasons why they're doing it. And I come with my scientific knowledge, then we meet together and come up with an ideal solution. There are good reasons why they do things, which give them money...In science, we always keep things constant and look at one thing at a time, but with them, everything is happening all at once. We try and interpret what is happening and come up with an ideal solution*."

"*As the crops are growing, we are taking pictures, looking at the soil and the water and how the plants are growing*," says Mpuisang. "*It's a live experiment. Even if you are not the one planting, you become part of the farming system*."

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