Goat and Sheep Technology Toolkit Catalogue

TAAT Clearinghouse

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Front cover photographic credits: Youth Agripreneurs protecting their newborn goats (left) and vaccination of goats against the *Peste des Petites Ruminants* disease (right) (photo credits TAAT and ILRI). Background a cured goat hide.

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Purpose and Introduction

This catalogue describes a series of proven livestock technologies that promote increased productivity and transformation of small ruminant production in Africa. It is developed through a collaborative effort from the Technologies for African Agricultural Transformation (TAAT) Program that seeks to increase stakeholder use of proven agricultural technologies, and its Small Livestock Compact project partners. The TAAT Small Livestock Compact, led by the International Livestock Research Institute (ILRI), supports a wide variety of stakeholders through capacity development and technical outreach, and this catalogue contributes to knowledge dissemination of those efforts. The TAAT Program identified several proven technologies that advance goat and sheep production. These technologies constitute a "technology toolkit" meant to promote understanding and stimulate adoption and investment into the modernization of livestock enterprise.

About TAAT. Weaknesses in the production and supply of commodities are viewed as responsible for Africa's food insecurity, need for excessive importation of food, and unrealized expansion of Africa's food exports. The TAAT Program led by the International Institute of Tropical Agriculture (IITA) pioneers new approaches to the deployment of proven technologies to African farmers. TAAT arose as a common effort of IITA and the African Development Bank (AfDB); and is an important component of the latter's Feed Africa Strategy. Currently, TAAT is advancing 100 carefully selected technologies through 88 interventions in 31 countries organized around 15 "Compacts" that represent priorities in terms of achieving Africa's potential in achieving food security and advancing its role in global agricultural trade. Nine of these Compacts relate to specific priority value chains of small livestock (including poultry), fish, common bean, rice, wheat, maize, cassava, sweet potato, sorghum and millet. Together these Compacts design interventions in collaboration with national programs to introduce technologies and innovations intended to meet ambitious targets for agricultural development. In many cases, these targets are addressed through the implementation of projects resulting from sovereign country loans awarded by development banks, where TAAT's role in the design, planning and execution of these loan projects is a vital element of their success.

Goats and sheep are compatible farm assets

The TAAT Top 100 Technologies. The Clearinghouse developed a database of the Top 100 Technologies that are transforming African agriculture. It is based upon the approaches of the TAAT Commodity Compacts but also includes those from the Consortium of International Agricultural Research Centers (CGIAR) that are recently described as ready for next user. These technologies are divided between those involving improved genetics and plant and animal breeding (23%), those based upon the distribution of digital information (3%), production input products of proven efficacy (21%), crop and animal management technologies of utility within agricultural extension messaging and campaigns (27%) and the availability of appropriately designed labor-saving equipment (26%). These technologies have a direct role towards the achievement of the Sustainable Development Goals in relation to farm productivity, food security and hunger reduction, improved household nutrition and diets, economic growth, climate-smart innovation, and improved human equity.

The Top 10 Small Ruminants Technologies. This catalogue describes goats and sheep as farm assets and then presents ten technologies that serve to modernize small ruminant production systems. These technologies include: 1) Herd improvement through community-based breeding, 2) Reduced overgrazing and rangeland rehabilitation, 3) Part-time containment in protective sheds, 4) Pasture improvement with grasses and legumes, 5) Cut and chopped fodder as feed, 6) Short-term fattening and supplemental feeding, 7) Thermostable vaccines for PPR virus eradication, 8) Processing and application of composted manures, 9) Humane slaughtering and meat inspection, and 10) Hide curing and secondary leatherworks. Details on each of these ten technologies are included in the catalogue.

Goats and Sheep as Farm Assets

West African Pigmy Goat is well suited to mixed farming systems

Among millions of African households, raising goats and sheep as small livestock is an important means of livelihood, a readily disposable source of cash for family needs, and an important element of social functions, such as religious and marriage ceremonies. Small ruminants are multi-purpose, valuable animals, especially in subsistence and pastoral communities. They are good sources of animal protein, in form of meat and milk, which enhance family food and nutrition security, and aids cognitive and mental development in children. Small ruminants provide income and employment to their owners and millions of others employed in the goat and sheep value chain as traders, butchers, processors, and consumers. Goat and sheep also provide wool and hide for clothing, shoes, and upholstery. Manure from these small ruminants is a good source of organic inputs to soil.

The popularity of raising goats and sheep results from their low start-up costs, ease of management, feed use efficiency, and hardiness to harsh weather conditions. They are adapted to different production systems, including pastoral, and mixed farming systems. Under favorable conditions and management, they offer reasonable return on investment, however, their productivity is considerably reduced among unimproved breeds. Improved breeds also offer resistance to harsh weather and diseases, more rapid weight gain and greater milk production. Both goats and sheep benefit from improved confinement and feeding, as well as vaccination against deadly disease.

Goats and sheep are raised for similar purposes but have many differences that affect their management. They are genetically distinct, the scientific name of goats is *Capra aegagrus hircus,* while sheep are classified as *Ovis aries*. They will occasionally mate, but offspring are rare because they have different numbers of chromosomes. An obvious difference between the two is the direction of their tails; goat tails point upward and sheep tails hang down, and sheep tails are wider. They also have different preferred diets; goats favorably browse the leaves and twigs of shrubs and sheep eat grasses and forbs. Even when raised together they behave differently, goats are curious and independent while sheep have a stronger flocking instinct. For this reason, sheep are easier to manage than goats. Goats exhibit more aggressive

Dorper sheep are well adapted to drylands of Africa

behavior and often dominate sheep, particularly when the sheep are hornless, but rams (male sheep) usually defeat bucks (male goats) in altercation because of their manner of horizontal attack. Such battles are not common as combat between males is associated with mating and the two animals tend to have different estrous cycles.

Merino ram (left) and bearded billy goat (right)

Physical differences extend to more than tails; goat hair does not require shearing while many sheep bear wool that can be sheared and marketed. The upper lip of goats and sheep are different. Most goats have horns, and many have beards. Many breeds of sheep lack horns and some bear manes. Goat horns are narrow and upright, sheep's horns are curled and cover the sides of their head. Sheep and goats have similar nutrient requirements, but goats are less able to digest roughage (cellulose), so sheep feed more efficiently. As a result, feeding grain to sheep is often more profitable. They tend to fatten differently with goats depositing fat around their internal organs and sheep layering fat externally. This difference is less pronounced in the warm tropics. Sheep are sensitive to copper toxicity, but this problem is seldom expressed under pasture and range management unless feeds are copper fortified or copper is used as a deworming agent. Sheep and goats are generally susceptible to the same diseases and internal parasites but goats tend to be more susceptible to worms than sheep. Cross infection between goats and sheep is common.

Note that complex multispecies grazing is the norm for natural ecosystems and many of its advantages translate into more resilient rangeland management. More efficient use is made from different combinations of grasses, forbs and shrubs resulting in increased carrying capacity, and reduced spread of invasive weeds and less palatable plants. Combination of sheep and goats is advantageous because of their low degree of dietary overlap, allowing the spread of grazing pressure more evenly across vegetation communities. The ratio of goats and sheep varies with vegetation, but in general equal numbers of both animals is advantageous in semi-arid rangeland. The price ratio between sheep and goat products is important in assessing their combined herd. In general, sheep products are slightly more valuable than goats. The advantage of mixed grazing increases even more when cattle are added, in part because cattle ward off predators. In general, there is one cow per four or five goats and sheep. In this way, animals of different grazing habits and biological capacities complement each other within a grazing system, offering both ecological and economic benefits.

A mixed group of goats and sheep in semi-arid Kenya

Technology 1. Herd Improvement through Community-Based Breeding

Summary. Poor genetics, and diseases are the most limiting factors for improved small ruminant production in Africa. Naturally selected, traditional goats and sheep exhibit useful adaptation to environmental stress and partial resistance to common diseases but are often lower in meat and milk production compared with improved breeds. One of the challenges of breed improvement in traditional smallholder systems is the mixed sex and age herd structure, which makes it difficult to identify and propagate specific male parents. Smallholder farmers usually do not maintain breeding records. This makes tracking genetic progress difficult and increases inbreeding. Attempts to improve the performance of local herds through crossbreeding with exotic breeds offers mixed results because offspring too often lack needed adaptation. These challenges underscore the need for more participatory community-based breeding backstopped by experienced animal technicians.

Technical Description. Heritable traits of interest in goats and sheep include birth weight, daily weight gain, weaning weight, mature weight, milk yield, percentage of twin births, and feed conversion efficiency. The community-based approach to breed improvement builds upon these traits of interest relying upon hardy stock performance. These programs are best established through collaboration between government, community and funding institutions and consists of nucleus and base herds. A nucleus herd contains at least two hundred selected ewes (female sheep) and does (female goats); and 8 to 10 recognizably superior rams (male sheep) or bucks (male goats), although many such programs are much larger, numbering into the thousands. A committee of community members selects the best young rams and bucks. Lead members manage these selected rams and bucks with mating based on phenotypic attributes. This pairing occurs within the base population of the best female stock. Breeding progress is supported through various performance measurements, often relying on ZPLAN software (first developed by the University of Hohenheim, Germany, and now applied to many local breeding efforts). These efforts must then be linked to feeding, health and marketing.

Herds are improved through breeding the best males and female based upon desired traits

Uses. Community-based breeding finds application across the tropics including with swine (in Vietnam), llamas (in Bolivia) and many countries with goats and sheep. Notable success is achieved in Africa with goats (Malawi and Uganda) and sheep (Ethiopia). Efforts are championed in Africa by both the International Center for Agricultural Research in the Dry Areas (ICARDA) and the International Livestock Research Institute (ILRI). An important role of the TAAT Small Livestock Compact and the TAAT Clearinghouse is to incorporate this practical breeding approach into the activities of country projects and within bank loans. Farmers within these programs provide animals with desirable traits to form the nucleus or base herds.

Composition. The nucleus herd comprises performance-tested stock. The breeder rams and bucks are assessed for three to five years and then matched with females from the base herd under the supervision of a management committee that breeds animals, arranges payment for breeding services, maintains performance records and monitors housing, feeding, herd health. Where needed, animal scientists provide specialist services related to breed characterization, rotation of breeding males, and data collection, analysis and interpretation of breeding success. Males are typically selected for their size, coat color, growth rate, mating ability and temperment. Females are selected for their appearance, coat color, mothering ability, age at first birthing, birthing intervals, and twining (having more than one offsping at once). Sheep may be further selected for their fleece and goats for their milk.

Application. Starting a program requires that target sites be identified, breeding stock characterized and ranked, and breeding objectives defined based upon different livelihood strategies and economic opportunities. Breeding operations require that elite animals be identified, recording systems be established and data be collected based upon a breeding plan. Maintenance of elite males used for mating is compared to natural breeding within members' flocks. This approach creates an enabling environment for goat and sheep enterprise that strengthens institutional relations, local cooperatives, and market linkages.

Commercialization and Start-up Requirements. The breeding program must consider technical, social, economic, and cultural aspects of small ruminant production, including market demands. From the design stage, the community should be involved in setting breeding goals, selection of elite stock and the management of the breeding flock. The community assumes ownership of the breeding plan, assuring compliance with all associated rearing practices, including the castration of males not meeting breeding criteria, and compliance with recommended land management practices. Members should be aware that relatively small incremental gains in the near-term result in real improvement over time.

Production Cost. The cost of establishing a community-based breeding program is relatively high and requires expertise outside of the community itself. For this reason, initial investment is required from government or donors. The bulk of the funding for establishing and operating a large community-based breeding program comes from donors and the public sector. Scientists and development specialists provide the expertise to design the program, data collation and analysis, and calculation of breeding gains, while local extensionists and community leaders oversee implementation. The overheads and operational costs of such a program can run into tens of thousand dollars annually. The community works with scientists to improve the indigenous animal breeds; and over time is expected to provide in-kind support and adhere to the program by contributing additional superior livestock, identifying local traits of interest and providing payment of enumerators and service providers.

Customer Segmentation and Potential Profitability. These breeding programs improve desirable traits of economic and environmental importance to both pastoralists and mixed farmers. Noticeable indicators include growth in herd size and incremental body weight. Data from Ethiopia suggest that membership in a breeding program increases family income by about 15% and allows three-fold increased slaughter for home consumption. Revenues may also be directed toward fattening activities that further increase incomes (see Technology 6).

Licensing Requirements. There are no licensing requirements for access to this breeding technology that exists as a Regional Public Good by ICARDA and ILRI, two CGIAR Centers.

Technology 2. Reduced Overgrazing and Rangeland Rehabilitation

Summary. Rising population and increasing demand for animal products place excess pressure on land leading to overgrazing and rangeland degradation. This situation results in soil erosion, nutrient depletion, water scarcity and loss of biodiversity; and too often leads to conflicts between wandering pastoralists and sedentary farmers. Climate change exacerbates this situation, yet technologies exist to combat rangeland degradation. What may be lacking is the investment to empower communities to act locally to reduce the negative environmental impacts of overgrazing and land degradation, and the political will to resolve conflicts, allowing communities to take decisive actions that better manage their pastures and rangelands.

Several options are available to reduce and reverse rangeland degradation (photo: FAO)

Technical Description. Successful rangeland management involves access to both grazing areas and water points; and regulating the movement of herds across and between them. Overgrazing occurs when the carrying capacity of these lands is exceeded, or when grazing animals overstay on land. Available technologies to combat rangeland degradation includes rotational grazing, afforestation through silvo-pastoralism, fodder production, improved pasture management, sustainable intensification of ruminant production, soil and water conservation, and policy interventions. The carrying capacity is based upon quantifying Tropical Livestock Units (TLU) that are supported on one hectare of land throughout the year. This is equivalent to about ten small ruminants on one hectare of established pasture and as little as five or six animals on drier rangeland. Stocking rate is increased through the introduction of improved forage species and better grazing management. Appropriate stocking reduces overgrazing and allows for land recovery. Silvo-pastoralism incorporates more trees into rangeland, usually through the introduction of fast-growing leguminous trees; acting to provide forage and fodder, shade, and windbreaks. In some cases, shrubs may be planted along the slope contour to control erosion and improve water capture.

Uses. Rangeland management and rehabilitation is critical to maintaining the ecosystem services across large areas of Africa utilized by pastoralists and agro-pastoralists. These lands are of particular importance to climate change mitigation. Grazing management is a priority across the Sahel as a means to combat desertification. Rehabilitation addresses multiple land degradation challenges including feed scarcity, soil erosion, soil fertility depletion, water conservation, carbon sequestration, and income generation. “Participatory Rangeland Management” facilitates engagement of stakeholders to work together within innovation platforms to improve the management of rangeland. Steps in this process include identifying

Grass strips as erosion control structures

at risk rangeland resources and users, linking to rangeland management institutions to develop response plans and stakeholder agreements, assigning new roles to various stakeholders that address declining productivity, and providing local communities increased control in this process.

Application. A key aim of rangeland management is to achieve improved and sustained ecosystem services and provide better livelihoods among affected stakeholders. This involves better management of vegetation, water, and soil, with particular regard to the forage and fodder those lands provide. Outcomes include maintaining vegetation cover, arresting water and soil loss from uncontrolled runoff, and reducing encroachment of invasive, less palatable bush and tree species. Management mechanisms involve adjusting grazing intensity, controlling the movement of livestock, matching herd composition to rangeland vegetation and existing wildlife, and controlling activities around water points. Key is rotational grazing, periodic re-seeding, water harvesting, and monitoring incremental gains. Controlled grazing may require destocking to have fewer, more productive animals or replacing larger (cattle) with smaller ruminants (goats and sheep).

Commercialization and Start-up Requirements. There are various opportunities to commercialize rangeland restoration. Interested parties can establish nurseries of desirable species of leguminous trees and browses. The World Agroforestry Centre and the United Nations are promoting initiatives for afforestation and rehabilitation of degraded rangelands. Conflict resolution for limited resources between pastoralists and farmers includes opportunity to promote better planned ranching and small ruminant production.

Production Cost. The set-up costs of a business in any one of the rangeland rehabilitation areas depend on the intended point of intervention and scope. International development partners are willing to support community initiatives to overcome rangeland degradation and protect the environment. A modest investment of about US $500 to $2,500 may be sufficient to establish a nursery of fodder trees and pasture grasses. This includes the cost of seeds, container bags, water pumps and hoses, solar powered wells, potting soil or compost, construction of a small shed, and seedling marketing/distribution costs. In contrast, establishing a semi-intensive small ruminant business costs between US $5,000 to $10,000.

Customer Segmentation and Potential Profitability. Adoption of technologies for degraded rangeland rehabilitation is open to all, but livestock producers and other entrepreneurs in the value chain are the major stakeholders. A modest return on investment of 15% to 20% can be realized from investing in fodder production and pasture improvement over a period of four to six months, with additional returns realized over the longer term.

Licensing Requirements. There is global concern and initiatives for the rehabilitation of degraded lands. The technologies discussed in this section represent Regional Public Goods developed or funded by a wide assortment of international agriculture development partners. There are no licensing needs for most of these technologies within a development context.

Technology 3. Small Ruminant Containment in Protective Sheds

Summary. Under extensive livestock production systems, goats and sheep spend days browsing and nights in open fields or makeshift confinement. Poorly confined animals are exposed to predators and theft and must roam excessively to feed. At the same time, close cohabitation with humans predisposes livestock producers to infectious diseases that spread from animals to humans. Housing is particularly important to young animals by protecting them from inclement weather and providing better feed, waste management and biosecurity. Small-scale farmers may not be able to afford the cost of building elaborate shelters, but designs are available to construct simpler shelters using locally available materials. This section provides some guidelines for constructing such shelters.

Upper-end protective containment of goats and sheep

Technical Description. A shed can be built from locally available materials such as timber, bamboo, or lumber off-cuts in combination with wire and fencing. These sheds usually include access to nearby daytime grazing. Proper shelter includes feed and water troughs that may be wooden, metal or plastic, sometimes fed through automated devices. The shed should be well drained and ventilated. Floors are best raised and made from wood or other insulated material. Once weaned, kids and lambs are best kept separately from adults, requiring between 0.2 to 0.3 m^2 for up to three to four months, increasing to 1.5 m^2 or more over time.

Uses. Low-cost containment sheds are more common among mixed livestock-crop farmers than pastoralists, the latter preferring fences of natural materials (or bomas) to structures. These sheds are common features across smallholder farming areas in Cote D'Ivoire, Ethiopia, Ghana, Kenya, Mali, Nigeria, Uganda and elsewhere. To a large extent, weather and location dictate the design and materials used. In the lowlands, more space and open designs permit ventilation and cooling, in highland areas sheds are designed to conserve heat, and in less populated places priority is placed upon excluding predators. Under warm conditions, shade trees are advantageous.

Age (m)	Inside shed space m^2
0-3	0.20 – 0.30
3 – 9	0.60 – 0.75
9 – 12	0.75 – 1.00
>12 Ewe/Doe	1.50 - 2.20
>12 Ram/Buck	2.50 - 3.50

Space requirements for small ruminants of different ages

Composition. Floors are best raised to 1 m aboveground and composed of wooden planks 2.5 cm or more thick. A gap of 1 cm placed between planks allows urine and feces to drop to the ground. Wider slits predispose animals to leg injury. Alternatively, PVC, non-slip flooring is commercially available for purchase online and from

livestock accessory sellers. Side walls are built with brick or wood to a height of 0.5 to 0.75 m and the upper wall finished with wire mesh to a height of 2.5 m. Gable roofing of corrugated sheets is preferred. Extended eaves 0.5 m from the wall provides better shading and protection from rain splash, and allows space for externally mounted feeding troughs. In some cases, nylon or tarpaulin covers are attached to the eaves, and dropped for protection from cold and inclement weather. Where possible, smaller, separate sheds confine and isolate sick animals.

An open structure suitable for warmer areas

Application. Sheds in the tropics are best built along an east-west orientation for better shading. The size is determined by the number of animals to be housed. A practical size is about 12m x 8 m (or 96 m^2), able to accommodate 50 or so adult females. Other complementary structures are dipping tanks or a spray race, a weighing bay, gangways for controlling flock movement, and a feed store. It may be advantageous to establish fenced grazing areas around the shed.

Commercialization, Start-up Requirements and Production Cost. Designs for modular sheds are available, as are those intended to combine poultry and ruminant operations. Simple mobile sheds for housing 5 to 10 goats or sheep can be constructed of salvaged materials. Ample opportunities exist for artisans such as masons and carpenters to specialize in constructing larger livestock shelters. The costs of constructing low-cost sheds for small ruminants depends on the type and quality of materials used, and available skills. In villages, where farmers have access to inexpensive wooden posts and planks, and that rely upon grass roofing, a suitable shed can be constructed for as little as US $200. Buildings that are more elaborate are constructed for about US $2,000 (at $20 per m^2). Market intelligence allows harvests during periods of peak demand, particularly festive seasons.

A simple open animal shed best surrounded by a fenced grazing area

Customer Segmentation and Potential Profitability. Smaller and less elaborate structures are useful to small-scale producers intent on meeting their household needs for meat and milk. Larger and more complete structures are suited to those engaged in commercial production. The profitability of the sheds is measured in terms of reduced mortality, theft, and feed wastage. Every young goat or sheep protected reflects a savings of about US $150. Every female animal saved translates to increase of 6 to 10 offspring over their reproductive lifetimes. A shed housing 50 animals can accrue value of US $12,000 over a few years.

Licensing Requirements. There are no licensing requirements for building low-containment small ruminants shed, but larger structures fitted with water and electricity may require building permits.

Technology 4. Pasture Improvement

A pasture planted in Bracharia, a highly productive perennial grass

Summary. Pastures are tracts of land that support grass and other vegetation eaten by grazing animals. Pastures are usually established and fenced, and receive inputs such as fertilizers, seeds and irrigation that improve the amounts and quality of feeds derived from them. In this way, they are distinct from rangelands that are for the most part managed less intensively and less directly. Like rangeland, however, pastures degrade when overgrazed, resulting in the loss of the most nutritious plants and replacement with less productive ones. Pasture improvement refers to efforts that maintain the best species and support their productivity. Several different approaches are followed in the establishment of pastures such as control of weedy patches, partial land disturbance and sowing of improved grasses and legumes, under sowing croplands with grazing plant species allowing for the establishment of crop-pasture rotation, establishment of shrub hedgerows along pasture margins and contours, and planting vegetatively propagated perennial grasses with greater productive capacity. In some cases, land is deliberately overgrazed and over sown with improved seed so that it establishes under less competition. Pastures typically contain watering troughs and are provided with supplemental feeds, and structures may be located nearby for nighttime confinement (see Technology 3). Note that pasture not only refers to the tracts of grazed lands but also to the vegetation that is grazed.

Technical Description. Grasses and forbs obtained from pasture are a practical and affordable source of feed for goats and sheep. This is because purchased feed is too expensive for most small ruminant producers. As a result, knowledge of pasture establishment and management is a valuable skill among animal producers, allowing for greater production than from rangelands. Selection of pasture species depends on climate, with annual grasses grown in the driest areas and perennial grasses in wetter ones. Pastures are established by sowing seeds, and in some cases planting sprigs and stems of perennial grasses. In many cases the land is first plowed and fertilized during the early rainy season and allowed to establish for several months to one year. Pasture management practices include re-seeding, weeding, slashing, burning, and controlled grazing. Over time, weeds invade pastures, reducing their productivity and may be treated with selective herbicides. Note that livestock should not access pastures for one to two weeks following treatment with herbicide.

Uses. Pastures can be grazed directly by animals or cut and fed to small ruminants in stalls (see Technology 5). Goats and sheep eat the equivalent of 2% to 5% of their body weight in dry matter daily but leguminous fodder should not exceed 1/3 of this because of the risk from bloat. Grazing animals should have access to a salt lick and water. One success story relates to the pasture grass *Brachiaria spp.* that Increases milk production and weight gain. It offers high biomass, nutritious feed, and drought tolerance, and is well suited to making hay. Interest in this pasture species has spread to Cameroon, Ethiopia, Malawi, Mali, South Sudan, Somalia, Sudan, Tanzania, Uganda, and South Africa, in part through the efforts of TAAT.

A pasture with alternate hedgerows of the legumeous tree Leucaena leucocephala

Composition. The best pasture grasses in Africa include *Chloris gayana, Brachiaria mulato*, *Pennisetum purpureum, Hypherrania rufa, Panicum maximum*, *Andropogon tectorum and Cynodon dactylon*. These may be planted with leguminous ground covers and shrubs. Typical input rates of seeds are 10 to 25 kg per ha, and fertilizers 50 kg per ha, with smaller seeds required in less amounts. Often, legume seeds are accompanied with phosphate fertilizers and seed inoculation.

Application. When designing a pasture and selecting its composition, livestock producers should consider the climate and soil, and in some cases provide irrigation and soil amendments. Some basic options for establishment follow as different approaches to pasture establishment exist. Broadcasting involves modest soil disturbance and sowing, with or without fertilizing and irrigation. Sowing improved seed into existing pasture usually takes place after close mowing, overgrazing or burning. Sowing pasture species into the understory of cereal crops allows for crop-pasture rotation. Vegetative propagation involves stem cuttings of perennial grasses introduced at the beginning of the wet season. This is commonly performed with Napier grass (*Pennesetum purpureum*). One option not considered in detail in this catalog is hydroponic fodder production that involves planting cereals seeds such as wheat, maize and sorghum in trays lacking rooting media. Seeds are soaked in water and spread across the trays and watered regularly until the seeds germinate and form solid stands of seedlings after seven to ten days. Both the shoots and roots are fed to animals as a nutritious feed supplement. Do not use seeds treated with insecticides or fungicides for this purpose.

Commercialization, Start-up Requirements and Production Cost. Commercialization options in pasture production include grazing animals, cutting and selling fodder, and pasture seed production and marketing. Other value addition to pasture is through silage making, and hay bailing. The cost of new pasture establishment with improved perennial grasses is approximately US $400 to $600 per ha allocated at about 10% land preparation, 13% weed control, 27% fertilizer and 50% seed, spread over several years. Higher costs reflect the inclusion of pasture legumes and their accompanying inputs. Operating costs are about US $40 per ha per year, offering additional feed worth between $150 and $200 per ha per year.

Customer Segmentation and Potential Profitability. Improved pastures are established by livestock producers intending to upgrade their feed supply and rangeland productivity, and by farmers engaged in integrated livestock-crop production. Even small-scale farmers can benefit from allocating a small part of their land to pastures in terms of improved supply of meat, milk, and manure to the household.

Licensing Requirements. There is no licensing for establishing pastures, but land managers must be assured of land tenure. Converting forests to pasture leads to deforestation and carbon emissions, and land managers may legally be prevented from doing so.

Technology 5. Cut-and-Carry Fodder Systems

Summary. Under more extensive livestock production systems, small ruminants graze on vegetation growing on rangelands and pastures, often moving from place to place according to the season in search of food and water. An alternative approach is to feed animals through "Cut-and-Carry", where feed is gathered and offered to confined animals; a system also referred to as zero grazing. Cut-and-Carry facilitates more efficient feed management by reducing wastage; but also places greater demand on labor and nearby vegetation resources. It also secures maximum advantage from crop residues and seasonally available vegetation. It allows for earlier returns, for example after weaning at four months, small ruminants raised under the Cut-and-Carry system can be fattened to 35 kg in only six months compared to 15 or more months under traditional grazing. Cut-and-Carry also facilitates the collection and use of manure as a valuable farm asset (see Technology 8). In this system, animals can be confined and wholly dependent upon feed delivery (i.e., zero-grazing), or partially confined where animals intermittently graze in and around the homestead.

Sheep feeding under confinement in Ethiopia, where cut and carry is widely practiced

Technical Description. During free-grazing, large proportions of feed are lost due to trampling and contamination with urine and feces. The Cut-and-Carry system requires that fresh vegetation, usually grass, be cut daily and fed directly to contained livestock. It first came to prominence with dairy cattle but is also applicable to goats and sheep being raised for milk and meat. The main components of this system includes animal housing (see Technology 3) equipped with feed and water troughs, a continual and productive source of edible fresh vegetation (see Technology 4) and means to effectively cut and transport plant biomass. Cutting and transport is increasingly performed using power equipment. Fodder should be chopped into smaller pieces using either manual or power choppers. Feeding troughs can be constructed from wood, plastic, or metal, and be either free standing or attached to other structures. A 200-liter drum cut longitudinally in half and mounted onto a frame is a useful design. Troughs must be durable and stable to withstand trampling and being tipped over, provide ready access to feeding animals, and minimize risks of fecal contamination. Supplemental feeds accelerate weight gain and improve animal health, typically combining cereal grains, minerals and vitamins. Note that sheep do especially well on supplemental cereals, accumulating layered fat that increases their value (see Technology 6).

Uses. Cut-and-carry fodder systems are widely practiced in Ethiopia, Ghana, Kenya, and Nigeria, with large amounts of land devoted to the production of fodder biomass. A modified system is practiced in the Sahel where animals graze during the short rainy season, stubble graze following crop harvest and then fed stockpiled materials for the rest of the year. The system occurs in Burkina Faso, Mali, Niger, and Senegal, relying upon maize, sorghum, and millet stover as well as the haulms of grain legumes.

Composition. In dryland areas, fresh biomass is available for only part of the year so stockpiled crop residues constitute a major feed source. In wetter areas, some cropland is earmarked for production of large-statured perennial grasses such as Napier or Brachiaria; and cut throughout the year. Therefore, land allocation and crop residue management are key components of this feeding system. The quality of the fodder and crop residue depends on the time of harvest, the method of collection and preservation. Grass and crop residues may be harvested and dried in the field to about 12% moisture, allowing them to be stored for weeks or months.

Supplemental feed offered in a trough (above) and cut shrubs on a hanging rack (below)

Application. Producers adopting Cut-and-Carry must have a suitable livestock shed, access to land and vegetation, sufficient labor, access to additional feed and veterinary supplies, and a premium market for their higher quality animal products. Goats and sheep require that well-balanced diets be delivered to them with goats preferring leaves of herbaceous plants and sheep favoring grass. Animals consume up to six kg of fresh fodder per day, depending upon their stage of development. A lamb worth US $80 consumes fresh chop worth US $30, supplements and medicines costing US $40 and then produces meat worth US $224 and manure worth US $6, offering returns of about 150% over six months.

Commercialization, Start-up Requirements and Production Cost. It is moderately expensive to implement Cut-and-Carry fodder systems assuming sufficient vegetation is available, and it is labor intensive to supply sufficient fresh feed daily. Access to improved breeds (see Technology 1) offers decided advantage. Operators must hold skills in animal diets, health care and market intelligence to capitalize on their additional investment. As described in Technology 3, a suitable shed may be constructed using mostly local materials for as little as US $20 per m^2. Feed and water troughs can be fabricated for 20 to 50 animals for only US $50 to $100. Sufficient skills are available in rural areas that meet labor requirements for chopping, feeding, and cleaning. A young animal costing US $80 may be raised for four months for about $70 and sold for a considerable profit (see above).

Customer Segmentation and Potential Profitability. Cut-and-Carry involves client segmentation. Not all animal producers are prepared to practice this feeding regime, preferring traditional rangeland grazing or open pastures. Not all farmers are willing to sacrifice croplands to raise fresh animal feed throughout the year. Not all customers are willing to pay the premiums that better managed livestock command. Nonetheless, Cut-and-Carry and zero-grazing systems will inevitably expand because they are compatible with demands of peri-urban agriculture and more sophisticated consumer preferences. Note that a Cut-and-Carry shed can produce three batches annually, providing reliable income.

Licensing Requirements. There are no licensing requirements to establish a cut-and-carry system although there may be restrictions in raising animals in and around urban areas.

Technology 6. Short-Term Fattening and Supplemental Feeding

Summary. Goat and sheep fattening results from intensive and nutritious feeding to promote fast growth and fat deposition, attaining desired carcass growth and quality. It maximizes the value of livestock across minimum time and space, approaching value addition to purchased stock as a business venture. It requires moderate investment and reduced labor, and has minimal risks; allowing peri-urban dwellers to become engaged in small ruminant value chains. Young adult animals are purchased and fattened to slaughter weight by limiting their movement and providing them a concentrated diet containing less roughage. This fattening is readily visible over a short period of time, resulting in quick profits and rapid turnover of stock. Selection of initial stock is extremely important, with some breeds known to adjust better to fattening conditions and diets. Males fatten more rapidly when castrated. Unhealthy animals fatten slowly, and once purchased animals are often treated for intestinal parasites. Goats and sheep may be fattened within three months. Despite a resemblance to Cut-and-Carry systems (Technology 5), many differences between the two approaches exist.

A goat fattening pen to maximize weight gain and improve carcass quality

Technical Description. Goat and sheep fattening, sometimes referred to as "finishing", involves intensive feeding of animals within feedlots to slaughter weight with adequate fat deposits. Its approaches are based upon established business models, recognizing that local and urban markets have high demand and are willing to pay higher prices for properly finished animals. Its approaches can reduce fattening intervals from as much as 18 months for grazed animals to only three months from properly selected and fed ones. In this way, finishing facilities are often located near livestock markets and slaughterhouses, and may conduct three rounds of fattening per year, often targeting their supply of fattened animals to festive seasons when demand and market prices are highest.

Youth demonstrating how to select sheep for fattening at an Ethiopian livestock market

Uses and Composition. Fattening is conducted as a separate business venture in several countries including Burkina Faso, Ethiopia, Kenya, Mali, and Nigeria. Sales of fattened bucks and rams targets the Eid-Mubarak festival among Muslim populations, and the Easter and Christmas seasons in Christian areas. Feed concentrates for small ruminants, sometimes

Mixtures of low-grade grains (top) and extruded pellets (bottom)

called rations, are rich in energy and protein but low in fiber. The ingredients for making a balanced supplement feed include kernels of maize, sorghum, millet, and wheat as energy sources and soybean meal, cotton seed cake, fish meal, groundnut cake, or other oil seed meals as protein and oil sources. Minerals are provided as bone meal or calcium carbonate. Goats and sheep consume over 1% of their body weight as feed concentrate daily.

Application. Initial selection of stock for fattening is critical; animals must be healthy and without physical defects. Avoid emaciated or weak animals as they require excessive time to recover. Chose animals with large skeletal frames as they have greater potential for gain. Among males, castration influences fattening and tastiness of meat. Some breeds have better potential for growth and fattening and adjust to fattening regimes more quickly. Avoid older animals (beyond four years old) as they are not suitable for fattening and select those at least 20 kg in weight. Avoid underfeeding and minimize movement. During the first two weeks of fattening, include grass and hay in diets, and then reduce their proportion over time. Where possible, sort animals based on weigh and gender, and raise them as groups. Provide rations and fresh water throughout the day and night. Some animals do not adjust to intensive feeding, and once identified cull them from the fattening stock as soon as possible. Each animal requires 15 to 20 linear centimeters of feed access. Shelters should be cleaned regularly minimize threats of pest and disease. Where possible, reduce feed costs by blending available materials in established proportions. Upon purchase, all animals should be ear-tagged for identification, dewormed, and weighed weekly.

Commercialization, Start-up Requirements and Production Cost. Commercial start-up requires availability of improved breeds at favorable prices, access to feed and supplements, availability of shelter and troughs, and access to health services. Fattening young rams may offer the best opportunity for value augmentation. A young animal costs US $80 and can be finished in four months at a cost of about US $70.

Goat fattening with excess feed and limited movement

Customer Segmentation and Potential Profitability. Fattening is profitable because of the value per unit weight increases as both body weight and animal condition improves. A finished goat or sheep sells for about US $230, offering a considerable profit with more than 50% net return in only a few months. This operation may be repeated three times per year over several years once facilities are secured.

Licensing Requirements. There are no licensing requirements for establishing a small ruminant fattening operation beyond simply rearing the livestock themselves, although special conditions may apply to enterprises in peri-urban and urban areas, especially those working in conjunction to slaughterhouses (see Technology 9).

Technology 7. Disease Eradication through Thermostable PPR Vaccines

Summary. "*Peste des Petites Ruminants"* (PPR) is a serious disease of goats and sheep across Africa. Also known as "sheep and goat plague", this is a fast-spreading viral disease with high mortality rates, especially among younger animals. Its symptoms are rapidly elevated body temperature, with affected animals displaying discharges from the eyes and nose, sores in the mouth, troubled breathing, coughing, foul-smelling diarrhea, and death. PPR is spread by airborne droplets from infected animals with the virus targeting lymph tissue. Incubation periods range between three to ten days. There is no cure for PPR, but mortality rates are reduced with antibiotics that prevent secondary pulmonary infections. The best control measure is achieved through vaccination, particularly when delivered through sub cutaneous injection at the age of 4 months and is effective for about four years. It is also important that producers be aware of this disease and isolate any infected animals at an early stage of development. Economic losses from PPR across Africa and Asia are estimated to be US $2.1 billion per year.

A goat showing severe symptoms of PPR infection

Technical Description. A homologous live attenuated vaccine protects small ruminants against PPR. Vaccination offers lifetime immunity for animals other than breeding bucks and rams. In the past, the main constraint limiting the widespread use of this vaccine within eradication programs was the requirement for cold storage maintain the stability of the vaccine. More recently, the development of thermostable PPR vaccine overcomes this challenge. Two such vaccines are available; the ILRI thermotolerant PPR vaccine produced by the Thermovac process, and Xerovac, an older vaccine. Both vaccines are proven effective in several countries and demonstrated stability at ambient temperatures up to seven days for Thermovac to two weeks for Xerovac, withstanding temperature spikes of 40°C. Both vaccines are central to eradication efforts mobilized by the World Organization for Animal Health and the Food and Agriculture Organization of the United Nations. The standards of the Pan African Veterinary Vaccine Centre of the African Union recommend thermostability of 25°C for 10 days or 40°C for 2 days. The advantages of a thermostable vaccine include reduced storage costs, improved vaccine effectiveness and increased coverage of more animals in less time.

Vials of thermostable vaccine ready for use

Vaccinating a young goat with the thermostable PPR vaccine

Improved awareness and proper early response are also important elements of eradication campaigns.

Uses and Composition. Massive vaccination campaigns are underway. During 2019 and 2020, FAO assisted in the administration of 50 million doses in several countries including Central Africa Republic, Eritrea, Guinea, Kenya, Liberia, Sierra Leone, South Sudan, Tanzania, and Yemen. The World Organization for Animal Health OIE also delivered 19 million doses of the vaccine to Burkina Faso, Mauritania, Togo. The TAAT Livestock Compact worked with NARS partners to administer 37,000 doses of the PPR vaccine to small ruminants in Mali and Ethiopia. Vaccine production is a highly regulated process under strict hygiene undertaken by accredited laboratories. The ILRI protocol and Xerovac thermostable vaccines are produced using the live attenuated Nigeria 75/1 vaccine strain. The process involves stabilizing agent and lyophilization but is not described in detail within this catalogue.

Application. PPR is a notifiable disease, meaning that outbreaks must be reported to national veterinary authorities. Disease surveillance is an essential component of control efforts that considers animal movement, quarantine of affected farms, and identification of high-risk areas with inappropriate biosecurity measures that threaten infection and spread.

Commercialization, Start-up Requirements and Production Cost. For reliance upon PPR vaccination to become the norm among small ruminant producers, thermostable vaccines must be both available and affordable. Producers must be willing to pay for the administration of vaccine and comply with the instructions of animal health professionals. These experts must be trained and certified according to national regulatory standards. The vaccine is relatively inexpensive as each administered dose costs between US $0.5 and $1.0 per animal. Vaccinators work in organized teams under the supervision of an experienced veterinarian. An investment of only US $300 is sufficient to mobilize a local animal health technician into profitable vaccination enterprise.

Customer Segmentation and Potential Profitability. Sourcing vaccines from the reliable suppliers, cold chain management and vaccine injection are regulated practices to ensure that administrated vaccines are effective. Consumer confidence is essential to eradication efforts and misuse can inadvertently introduce new diseases. All goats and sheep should be vaccinated regardless of their scale of production. A well-organized vaccinator can treat up to 5,000 animals per month and operate a business with a fair return on investment.

Licensing Requirements. Administration of vaccines and biologicals, including the thermostable PPR vaccine, is strongly governed by national authorities. Vaccinators and veterinarians are licensed to operate by national authorities, animal owners require no permits to do so, and are rather encouraged or required to have all their animals treated.

Technology 8. Processing and Application of Composted Manures

Summary. The manure from goats and sheep has economic value and realizing benefit must take into account the characteristics of this material. Some advantages of this manure are its relatively high and balanced nutrient content compared to other manures, and the characteristic of its drier, odorless, naturally pelleted form. These may be applied fresh to soil without damaging plants, or as a mulch or compost ingredient. Fresh or dried manure poses some hazards as they may contain human pathogens and weed seeds but composting readily deactivates these threats. Composting is relatively rapid, in part because the spherical shape of fresh manure pellets allows for natural ventilation of the pile, resulting in a rapid onset of aerobic decomposition. While these manures are valuable as inputs to crops and soil, at the same time commercial technologies are available to produce commercial organic fertilizers from them.

Fresh manure droppings on the ground (top), screened manure compost (center) and pelleted organic fertilizer (bottom)

Technical Description. Goat and sheep manure offer several advantages but also pose some disadvantages. Goat and sheep manures are excreted as pellets and are drier than many other animal manures, making them easier to collect and spread. They contain balanced nutrients (N, P, K) and micronutrients and do not burn when applied directly to plants, as does chicken manure, allowing them to be used either fresh, as mulch or compost material as situations warrant. These manures are nearly odorless, and do not attract many insects. These manures compost quickly, and work well as a sole composting ingredient, resulting in a uniform dark brown product suitable for commercial organic fertilizer. Pelletized droppings allow for more initial airflow through compost piles, accelerating the decomposition process. The finished compost can also be pelleted. The production and sales of manure-based organic fertilizers, whether dried, composted, or pelleted, generates income. Goat and sheep manure contain over twice the nitrogen compared to cattle manure. The main disadvantage of goat and sheep manure is that under free grazing it is extremely difficult and somewhat expensive to collect for processing. Instead, it simply enters naturally occurring nutrient cycles. The nutrients present in the goat and sheep urine is usually wasted unless the animals are penned and bedding applied to the floor (see Technology 3). Even when urine is collected as soaked into bedding, much of it is lost through volatilization of ammonia. Fresh goat and sheep manure may contain some human pathogens, so it is best to apply as composts to vegetable crops. This manure may contain weed seeds that are again destroyed by composting. Efficient use of manure constitutes a challenge both to livestock producers and the environment. Improper handling and disposal of untreated manure may result in methane emissions and pollution of groundwater and waterways unless precautions are taken, providing additional economic incentive for value added processing these manures.

Uses and Composition. Farmers across Africa utilize goat and sheep manure in its different forms. In some cases, manure collected from the livestock pens is exchanged locally for crop residues used as feed. In other cases, manure is collected and trucked longer distances to vegetable growing areas and to organic fertilizer processors. The simplest way to add value to manure is to keep goats and sheep in pasture-based systems (see Technology 4) where small ruminants spend days grazing and depositing manure into shelters at night while under protective confinement (see Technology 3). This manure may be collected and sundried to 15-18% moisture content, and then stored in piles or bags for up to 2 weeks before use.

Crushed and finely ground composted manure processed into organic fertilizer

The nutrient composition of goat and sheep manure is 25% organic carbon, 2.2% nitrogen, 0.3% phosphorus and 3.0% potassium. Goat and sheep manure are not strongly acidic. Aerobic composting extends this life, allows mixture with rejected feed and bedding, and under favorable conditions a marketable compost is produced within only four months.

Application. Composted goat and sheep manure is readily compressed into organic fertilizer pellets. These fertilizer pellets are convenient for application, transportation, and storage. After composting, production involves crushing, screening, granulating, drying and further screening for pellet uniformity. Crushing as achieved with a hammer mill able to process semi-wet material. Screening is performed whether in batches or continuously along a conveyer belt. Oversized materials are passed again through the crusher. Pelletizing is performed by exposing the fine material to small amounts of added water and friction from stirring, or on a vibrating granulating pan. Alternatively, pellets may be formed by extrusion. A second screening permits collection of undersized materials and their reuse. Drying is most effective by conveyer passage along a heat tunnel, but in some cases may be achieved through air drying.

A commercial organic fertilizer prepared from sheep manure

Commercialization, Start-up Requirements and Production Cost. Entrepreneurs invest in the acquisition of compost turning and pellet making machinery. Manure drying and composting equipment able to process between 5 and 10 tons per day cost about US $5,000 to $10,000, including installation.

Customer Segmentation and Potential Profitability. Manure use applies to the full spectrum of small-scale to commercial farmers. Regulations against uncontrolled discharge of animal waste drives further investment in manure processing. Processed manure is sold for US $200 to $1,500 per ton depending on the level of processing and quality of packaging.

Licensing Requirements. There is no licensing requirement for operating simple, farm-level manure composting, however, national environmental and sanitary regulations may apply when installing a processing factory for drying, pelleting, and composting manure.

Technology 9. Humane Slaughtering and Meat Inspection

Summary. Humane slaughter refers to the killing of an animal instantly or rendering it insensible until death follows, without pain, suffering or distress. When slaughtering animals for food, this means they must be stunned prior to bleeding out so they become quickly unconscious. The most humane method involves massive blood loss so that death quickly follows. For goats and sheep, bleeding results from ventral neck cuts. Stunning is often achieved via electro-narcosis, a profound stupor produced by passing an electric current through the brain. Many devices are commercially available that produce this stupor. Another approved method of stunning involves percussion bolt pistols. At a deeper level, humane slaughter is based upon animal rights and that even those with utility as human food have moral worth, and their basic interest to avoid unnecessary suffering must be honored. This contrasts to the view that domestic animals are merely property with no legal rights of their own. Too often slaughterhouses place profit before welfare when it comes to ending animals' lives, but it is important that technologies that reduce cruelty be more widely recognized and used.

Delivery of electro-narcosis prior to the slaughter of a sheep (photo: Humane Slaughter Association, UK)

Technical Description. African countries have regulations surrounding humane slaughter and operate commercial abattoirs in which standard operational practices are observed for animal slaughter and processing. At the same time, animal slaughter also occurs in households and villages across Africa where humane transportation, stunning and bleeding of animals are not observed and remain unenforced. Humane treatment of animals from farm to the abattoir minimizes animal suffering, improves meat quality and health of consumers. Every aspect of livestock processing has humane considerations including transporting, restraining, stunning, and killing these animals. Like humans, animals are sensitive to pain and injury. Suffering and stress affect meat quality, resulting in biochemical changes causing less flavor and lower meat shelf life. Small ruminants are transported on hoof, by rail or by road. Transportation on hoof is the most stressful and accident-prone form of livestock movement. Animals may become dehydrated, bruised, or die from exhaustion. Animals may eat unfamiliar toxic plants or lose weight through unnecessary expenditure of energy without careful consideration of the travel route including grazing

Inhumane transport of goats using a motorcycle

Small ruminants transported vial a properly equipped truck (photo: Dreamtime.com)

and watering points. Local transport may also be overloaded in inhumane manner. In contrast, trucks equipped with decks and proper ventilation, non-slip floors and 0.4 m^2 per animal are recommended. Ramps inclined about 20 degrees allow stress-free loading and unloading of animals.

Uses and Composition. Humane operations within slaughterhouse and by meat processors allow these businesses to better comply with government regulations. Modular mobile slaughter abattoir and meat processing facilities are also available. Humane handling and slaughter of small ruminants involves overnight rest after transportation in adequately sized holding pens with access to feed and water, appropriate restraining equipment before stunning, stunning using effective devices, and bleeding within one minute of unconsciousness using approved tools and cuts. Delayed bleeding results in the rupture of blood vessels and accelerated meat decomposition. All stages of slaughtering and carcass dressing are subject to certified meat inspection.

Application. Humane animals handling is the responsibility of all livestock value chain actors, involving both farm- and abattoir-level infrastructure and processes. These include building the right animal pens, handling kraals and restraining cages, and following the prescribed conduct of animal management during slaughter. The technologies require well trained staff and compliance enforcement. Adequate water and electricity supply are required. In addition, waste management procedures must be established for compliant processing.

Bleeding of a humanely stunned small ruminant (FAO)

Commercialization, Start-up Requirements and Production Cost. Start-up requires a rigorous business plan, proper processing facilities, ready access to quality animals, and access to skilled labor allowing for strict hygiene, worker safety and exact compliance with regulatory procedures. These abattoirs are run as either public facilities intended to serve communities or private businesses, but both must meet regulatory standards. Establishing modern facilities requires between US $75,000 to $250,000.

Customer Segmentation and Potential Profitability. The absence of publicly owned abattoirs in smaller towns and villages opens wide the opportunity for private abattoirs to operate. The business is open to any entrepreneur who has been trained and licensed by the appropriate national authority. A modest investment of US

$2,000 to $2,500 is adequate to set up a goat and sheep slaughter slab. A modular mobile slaughter facility cost more. Privately owned abattoirs can slaughter 15 to 20 animals per day, depending on location and market access. By charging a modest fee per animal, an abattoir operator can make a profit of US $15 to $20 per animal. Operating an abattoir is win-win business because costs are charged per animal slaughtered and there are minimal recurrent expenses, allowing substantial return on investment when adding value to others livestock. Individual entrepreneurs in the meat processing value chain can also make money from selling dressed goat or sheep meat. Live goats and sheep are often sold at nearly 25-35% less than dressed meat. For instance, a 30 kg live goat can be purchased for US $50 to $60 but once dressed it can be resold for $80. With further value addition by restaurants and retailers, it is possible to obtain US $4.00 or more per kilo of goat and sheep meat.

Licensing Requirements. Operators are expected to practice humane small ruminant handling, sometimes in consideration with ritual requirements. Individual entrepreneurs require licenses from their respective national or local governments to establish slaughterhouses and meat processing businesses, including ones in compliance with environmental concerns as related to disposal of waste products.

Technology 10. Hide Curing and Secondary Leatherworks

Summary. Other than the carcass for meat, hides are the next most valuable product from livestock production. For this value to be realized, animals and their hides must be properly treated, and artisans require skill sets and appropriate materials. Value is lost when hides are cut and served as food with the carcass. Alternatively, hides are processed by local communities, stockpiled, sold, and fabricated by leatherworks industries into a variety of products for both domestic and export markets. Foremost among those products are shoes, handbags, and leather clothing, with premium value obtained through greater craftsmanship.

Well cured hides of goat (left) and sheep (right) offer potential for value-added industry

Technical Description. Depending on the intended use, animal hides are cured in ways that either retain or remove the hair. The raw hide is carefully removed from the carcass, scraped clear of any remaining flesh, treated with salt or brine, and stretched across a rack until dry, a process requiring between 7 to 30 days depending on the weather conditions. Salt pulls moisture from the skin and prevents flies from laying eggs that later result in putrefaction. After drying, hair may be removed by scraping, and then marketed for forward processing. Another, more advanced approach to curing involves initially soaking the hide in a solution of hydrated lime for 24 to 36 hours, de-liming in an ammonium sulfate solution (or vinegar) overnight, and then washing several times in clean water before stretching and drying.

A Woman's handbag made from goat leather (top) and additional value added through detailing (below) (photo: infonet-biovision)

Tanning results in relaxing and stretching the hide and preservation, often through treatment with alum and tannins. Once tanning is completed, the skins are washed a final time and subjected to final stretching and scrapping while drying, resulting in a smooth and pliable finish. Note that several African trees, particularly Acacias are rich in tannin and used in more traditional applications. Bleaching, polishing, and oiling are additional processes that can enhance leather utility and quality.

Uses. The curing of hide and secondary processing into leather is a common practice of pastoralist communities in Africa such as the Maasai in Kenya and Tanzania, the Fulani in northern Nigeria, Niger and Chad, the Peul and Fula in Mali and the Sahelian Tuaregs reaching as far north as Senegal and east as Chad. Their main leather products include pouches, sheathes, wallets, belts, tapestries, and rugs; all used in local communities, domestic trade, and export. Ethiopia and Kenya have advanced industries producing quality shoes for regional markets. Greatest value occurs when these products enter into the tourist trade.

Composition. The skinning knife is a very sharp knife that is used to peel away the hide from the carcass. The tanner knife as it is commonly known, is the primary tool for fleshing, dehairing, scudding and frizzing hides. This tool scrapes away membrane, fat and excess meat from the hide to ensure it will properly tan. A pair of rubber boots, an apron and elbow-long gloves are needed to protect against harsh tanning chemicals and cuts from sharp knives.

Application. Commercial tanning and leatherworks require competency but offer lucrative enterprises practiced as a cottage industry or at larger industrial scale. A realistic starting scale is the treatment of 10 to 20 hides at a time in 100-liter brining and tanning containers, relying upon as little as five chemicals and hand labor. Personal protection consists of plastic gloves, waterproof aprons, and boots.

Commercialization, Start-up Requirements and Production Cost. There is growing demand for leather products in Africa, and much of this may be met by young entrepreneurs relying upon local materials. A modest investment of about US $1,000 establishes a local leatherworks business. Business plans and financial analyses are available for operations of different sizes.

Customer Segmentation and Potential Profitability. Goat or sheep skin of about 0.5 m^2 are worth about US $7 each. It costs about US $1.5 to purchase a fresh hide and another US $2 to cure it, resulting in an investment return of about 100%. This is similar to the returns from processing and marketing cowhide, although goat and sheep leather are considered slightly more valuable per unit area. Hides cured with tannins using traditional methods are also considered more valuable than those cured with alum at industrial scales. Ultimately, the value of a leather good product is determined by the quality of the leather it is made from and the artisanship expressed in its fabrication, with the most esteemed fashion brands sold at remarkable prices.

Grassroots processing of hides for processing into leather goods

Licensing Requirements. Leatherworks require the handling and disposal of toxic and environmentally harmful materials and are subject to environmental licensing and periodic regulatory inspection beyond the requirement for business licenses.

Youth-led Small Livestock Enterprise

Youth are attracted to enterprises involving animals although that attraction is more toward poultry and aquaculture. In a recent review of 40 projects directed toward youth empowerment in agribusiness, it was concluded that 40% of all new youth start-ups involved animal enterprise, but most of these businesses (78%) practiced poultry and aquaculture with the remainder directed toward “small animals” including goats and sheep. This is attributed in part to the larger land area required for small ruminants and the proportionally higher start-up costs associated with building a herd, improving pastures and marketing products.

This need not be the case. In Kyotera District, Uganda, the ENABLE-TAAT Compact offered agribusiness training to youth. Some trainees then purchased as few as five improved breed sheep and herded them on communal land or lands abandoned by those who left for cities. Within eight months and with some additional investment from Equity Bank Uganda, the enterprise grew to 105 sheep, positioning it toward a profitable medium-scale business. One of these youth commented “There is so much grass around for the sheep to eat, and we get free vaccines from other herders in the community”. Now these youth are also moving into value addition opportunities as the enterprise expands.

Further evidence of the benefits from goat and sheep enterprise is reflected in the annual incomes earned by different categories of youth-led agribusinesses. Across all entrepreneurs, average annual income is US $2420 per year and only 32% of these businesses appear to be on a solid upward trajectory. Those raising fish earn US $2014 per year, and those raising chickens earn US $2640. Youth conducting goat and sheep fattening enterprises (see

Youth display newborn lambs from their growing herd in Kyotera District, Uganda

Technology 6) earn $2857 each, often working within partnerships, and their businesses appear to be growing. In this way, once youth are positioned to develop businesses involving small ruminants, their income generation potential looks bright. In addition, youth have developed parallel businesses, some involving the production of organic fertilizer from manures (see Technology 8), and others specializing in adding value to the hides of goats and sheep (see Technology 10). Demand for manure also exists among youth operating biogas fermenters as it provides a quickly decomposing anaerobic feedstock.

Strong attraction to goat and sheep fattening as a market enterprise also exists among youth in Borno State in northeastern Nigeria. This area is perhaps better known for insurgency rather than enterprise opportunity, but it interfaces with both pastoral and farming communities. Animal fattening proves a means of deriving quick benefit from seasonal surpluses of both animals and crops. Little space is required for fattening and required little investment (<US $2000) to convert peripheral market space into fattening corrals. Young adult animals are available at competitive prices and quality feeds are formulated from off-grade grains and crop residues. Timing fattening operations to festive seasons, particular the peak demand for fattened rams, resulted in strong demand and reliable profits, especially when plump animals were sent elsewhere for premium prices.

Lawan Kekeno Animal Fattening Enterprise in Borno State, Nigeria initiated through a small loan from the Agripreneur Movement

Another characteristic of youth-led animal enterprise is their attraction to smaller livestock, those smaller than small ruminants. In this case, this refers to rabbits (*Oryctolagus cuniculus domesticus*), grass cutters (or greater cane rat, *Thryonomys swinderianus*) and snails (*Achatina*

fulica and others). This sort of enterprise is often conducted as a profitable side business by youth in urban and peri-urban areas. Rabbits are kept in hutches and fed a mixture of fresh vegetation and pelleted feeds. A large population results from a single male and female. Several youths across Africa transitioned a small rabbit side business into a production and processing operation after developing needed skill sets and receiving modest loans from banks and development agencies. Grass cutters (Cane Rats) are esteemed in West Africa despite their appearance and are kept in cages similar to rabbits. Snails are kept in small backyard crowded enclosures, fed a wide variety of fresh vegetation daily, and earn about $1300 per year. The ability of snails to escape confinement, however, is uncanny.

Unlike the establishment of fishponds or poultry houses for large batches of broilers and layers, it is possible to enter into small animal enterprise as a sideline for little investment, and then accrue value over time as stock and herds grow. Confined stock requires little space and may be raised on under-utilized organic materials, and this forms much of the attraction youth feel towards these enterprises.

Rabbits (top), grass cutters (center) and snails (bottom) are prolific breeders and fed locally available materials

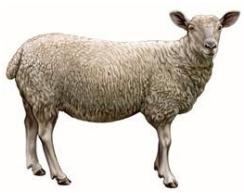
TAAT as Your Technology Broker of Choice

The TAAT Program offers its services toward the advancement of modernized agriculture. It brokers a wide range of needed technologies and bundles them through a process of co-design into winning solutions. It recognizes that modernized agriculture must serve as the main engine for economic growth in Africa and operates accordingly. Change is intended to achieve not only food and nutritional security but also to meet obligations under climate agreements allowing collaborative efforts to better combine global, national, and community-level interests. TAAT operates from a unique perspective to mobilize innovative solutions through better partnering that includes honest technology brokerage and effective, scalable skills development through five key mechanisms.

- ☑ **Unique understanding:** Expertise is offered in the areas of site characterization and problem identification.
- ☑ **Innovative solutions:** Leadership is provided in technology brokerage and solution bundling based upon a dynamic portfolio of candidate technologies.
- ☑ **Better partnering:** Assistance is offered in the better co-design and management of projects prompting agricultural transformation.
- ☑ **Replicable approaches**: Assistance is available to advance skill sets in technology brokerage and project management through customized Training of Trainers activities.
- ☑ **Honest brokerage:** An independent capacity for impact assessment and constructive learning is achieved through standardized monitoring and evaluation.

These partnership mechanisms are applied to the technologies featured in this catalogue as:

1. **Improved goat and sheep breeds** offering the latest advances in community-based breeding for flock improvement.
2. **Land stewardship** to increase pasture productivity, reduce range degradation and offer pathways toward rehabilitation.
3. **High-quality and affordable feed supply** to meet nutritional standards, accelerate growth rates, increase conversion efficiency and reduce production cost.
4. **Improved animal health** to prevent outbreaks of fast-spreading diseases, including more robust veterinary services and universal vaccination.
5. **More humane treatment and value-added processing** including more conscious transportation and slaughtering, greater sanitation precautions and maximizing processing of red meat and hides.



The TAAT Clearinghouse and Compacts are ready to assist in the design of national programs seeking to improve food and nutritional security, reduce importation of food and develop greater capacities to enter world trade through agricultural exports.

Conclusions

Pastoralists have several available technologies to improve their small ruminant production

This catalogue offers a suite of technologies useful in the rearing of goats and sheep within the setting of a small-scale African farmer or pastoralist. First, it establishes the similarities and differences between goats and sheep, describing the rationale and benefits from building enterprises around them. Herds may be improved through community-based breeding following different approaches, particularly built around identifying and sharing the bucks (male goats) and rams (male sheep) with the most favorable traits. Desirable females have a different set of traits useful to build herds and care for young (Technology 1). These small ruminants are often raised by grazing in drier rangelands, presenting the threat of land degradation. Some guidelines useful in land quality protection and rehabilitation include controlled runoff, establishing contour structures and periodic reseeding. Raising mixed herds allows for rangeland diversity and reduces weedy incursion (Technology 2). Alternatively, animals may be confined at night or throughout the day. The structures should be equipped with feeding troughs and water, and sufficient to ward off predators and thieves, but not be overbuilt to keep costs under control (Technology 3). Establishing fenced pastures nearby these structures assures sufficient feed, particularly when they contain improved varieties of grasses and legumes. In some cases, these pastures may be rotated with field crops, greatly improving land quality and system productivity (Technology 4). A more intensified approach involves Cut-and-Carry systems where animals remain confined and feed is delivered to them, mostly as fresh cut vegetation. Zero-grazing describes animals raised entirely under such confinement and allows for small ruminant enterprise under peri-urban conditions (Technology 5).

Short-term fattening and supplemental feeding are yet another enterprise and technology. Young adult animals are purchased, provided health care, and fed a diet that includes grains for three or four months until they fatten in a way that commands higher market prices. The key is in the selection of animals for short-term fattening as not all goats and sheep respond to such management (Technology 6). Blending one's own feed from low-cost locally available materials is a means to reduce fattening costs. Goats and sheep contract the deadly virus disease *"Peste des Petites Ruminants"* for which there is no treatment. Fortunately, animals may be vaccinated against this plague, and guidelines are provided that describe how vaccination campaigns may be conducted (Technology 7). The manures produced by goats and sheep also have value, but at the same time have characteristics that guide their collection and handling (Technology 8). Procedures and equipment are

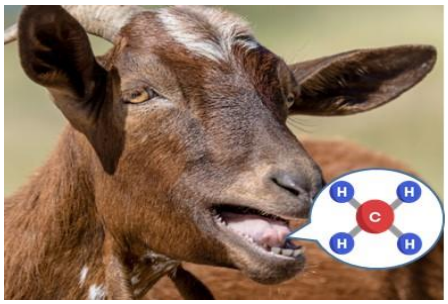
Dairy goats milked by machine

available that process manure composts into organic fertilizers, including pelletized ones. Humane slaughter refers to the killing an animal instantly or rendering it insensible until death follows, without pain, suffering or distress. This is viewed as an animal's right; even ones intended for food and otherwise regarded as property (Technology 9). Means of humane slaughter involving electro-narcosis are described. The hides of goats and sheep also have value for tanning and processing into shoes, handbags, jackets, and art, with premium value obtained through greater craftsmanship. This form of value addition extends the value chain and provides decent employment for artisans (Technology 10).

Shearing wool from a sheep in the highlands of Kenya

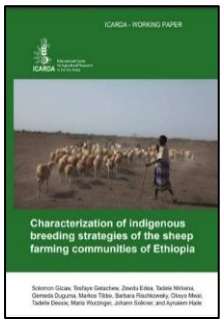
This catalogue does not cover small ruminant dairy or sheep wool. Together, goats and sheep produce only 3% of the world's milk supply, and mostly in temperate areas, so milking technology is not covered in this catalogue. Although all female goats and sheep produce milk to feed their kids and lambs, not all breeds produce sufficient supply for commercial milking. Three goat breeds suitable for dairy in Africa are the Nigerian Dwarf, Nubian and Saamen. Dairy goats produce more milk than sheep, but sheep's milk is richer in fats and well suited for making cheese. Similarly, this catalogue does no describe wool production and fabrication. Most meat breeds of sheep do not require shearing and do not produce wool in commercial commodities. Some wool production occurs in the African Highlands, however, and techniques to recover and process that wool are well established. Merino is a breed suitable for both meat and wool production.

Goats and sheep contribute directly to greenhouse gas emissions because they belch out methane as a by-product of their digestion. In addition, overgrazing and land degradation deplete rangelands of their terrestrial carbon stocks, and ammonia gas is emitted from manures and urea. Selective breeding of goats and sheep for reduced methane emissions is possible, but not widely practiced in Africa. An addult goat or sheep produce about 30 liters of methane per day. Animals with higher feed conversion efficiency generally produce less methane; a 10% higher growth rate reduces methane emissions by about 3%. Methane emissions is also controled by diet. Tannins, oils and other secondary compounds directly reduce methane production in the rumen. In general, goats produce less methane than sheep. Unfortunately, carbon benefits from methane emissions safeguards by goats and sheep are not recognized, but the co-benefits in selecting for decreased methane production include increased growth rates and profits from improved diets. Methane is also reduced through food additives such as seaweed, fats and oils, but these additives are not widely available at present. Nonetheless, biochemical ways to target digestion end-products of digestion in the rumen away from methane is a likely future tool for climate change mitigation. Further descriptions of climate-smart technologies from the Clearinghouse relating to livestock and cropping systems are forthcoming.



A goat belches methane from their rumen as they digest their food

Information Sources



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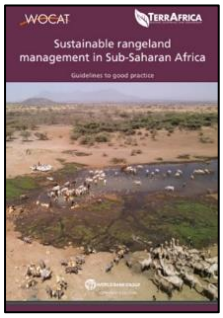

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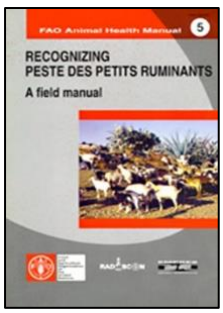

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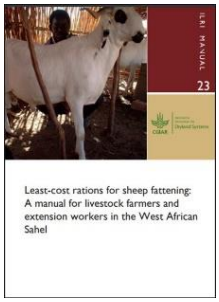

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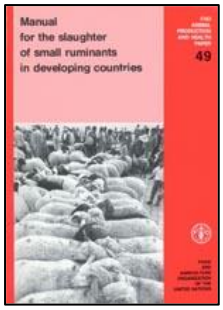

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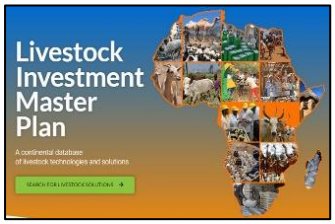

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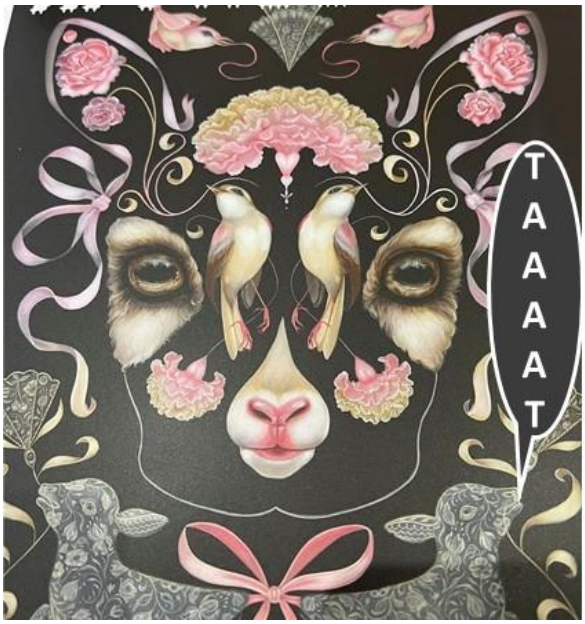

Technologies for African Agricultural Transformation (TAAT) and its Clearinghouse Office

The development objective of TAAT is to rapidly expand access of smallholder farmers to high yielding agricultural technologies that improve their food production, assure food security and raise rural incomes. This goal is achieved by delivering regional public goods for rapidly scaling up agricultural technologies across similar agro-ecological zones. This result is achieved through three principal mechanisms; 1) creating an enabling environment for technology adoption by farmers, 2) facilitating effective delivery of these technologies to farmers through a structured Regional Technology Delivery Infrastructure and 3) raising agricultural production and productivity through strategic interventions that include improved crop varieties and animal breeds, accompanying good management practices and vigorous farmer outreach campaigns at the Regional Member Country level. The important roles of sound policies, empowering women and youth, strengthening extension systems and engaging with the private sector is implicit within this strategy. The Clearinghouse is the body within TAAT that decides which technologies should be disseminated. Moreover, it is tasked with the responsibility to guide the deployment of proven agricultural technologies to scale in a commercially sustainable fashion through the establishment of partnerships that provide access to expertise required to design, implement, and monitor the progress of technology dissemination campaigns. In this way, the Clearinghouse is essentially an agricultural transformation incubation platform, aimed at facilitating partnerships and strengthening national agricultural development programs to reach millions of farmers with appropriate agricultural technologies.

Back cover photo: Pastoralist herding sheep (left) and youth actively engaged in sheep marketing (right) (photo credit International Livestock Research Institute). Background a cured sheepskin.

Goat and Sheep Technology Toolkit Catalogue

In collaboration with