Refining Animal Traction: Linking Physical and Social Processes

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Abstract

Draft animals provide tractive power to till the soil, transport firewood and water, and move crops from field to market. They provide meat, hides, and other byproducts for household use and income on about 250 million ha of land in developing countries worldwide. In Burkina Faso in West Africa, farmers with access to oxen are 'privileged' farmers, and the 70 % using only hand tools aspire to access draft animals. Few farmers can use wheeled tractors profitably because farms are small, farmland for expansion is scarce, and farm labor is plentiful. Animal traction makes full use of locally available resources, enhancing their efficiency and the resilience of the farming system. In our work there improving conservation tillage tools, rather than importing expensive technologies, we worked alongside local artisans to enhance their knowledge, skills, and abilities to build and repair the equipment using locally available materials.

Because of growing interest in soil health, local foods, climate-smart agriculture, and ecologically sound farm management, animal traction is regaining popularity in the U.S.A. For many draft animal practitioners, draft animals have social and cultural significance and embody a sense of community. The skilled application of animal power brings responsive and appropriate scale technology to demanding tasks such as tillage, planting, weeding, logging, and transportation. Most farms use mixed-power sources, animal traction in fields and forests, and motorized power for material handling. A cross-cutting theme is that practitioners' lifestyles converge around lower material consumption and a desire for a higher personal level of global well-being.

Kurzfassung

Zugtiere liefern die notwendige Zugkraft, um den Boden zu bestellen, Brennholz und Wasser zu transportieren und die Ernte vom Feld zum Markt zu bringen. Sie liefern Fleisch, Häute und andere Nebenprodukte für den Hausgebrauch sowie das Einkommen auf etwa 250 Millionen Hektar Land in Schwellenländern weltweit. In Burkina Faso in Westafrika sind Landwirt:innen, die Zugang zu Ochsen haben, "privilegierte" Landwirt:innen, und die 70 %, die nur mit Handwerkzeugen arbeiten, streben den Zugang zu Zugtieren an. Nur wenige Landwirt:innen können Traktoren auf Rädern gewinnbringend einsetzen, weil die Betriebe klein sind, die Anbauflächen knapp und die Arbeitskräfte reichlich vorhanden sind. Durch den Einsatz von Zugtieren können die lokal verfügbaren Ressourcen voll genutzt werden, was ihre Effizienz und die Widerstandsfähigkeit des landwirtschaftlichen Systems erhöht. Bei der Verbesserung von Werkzeugen für die konservierende Bodenbearbeitung arbeiteten wir nicht mit dem Import teurer Technologien, sondern mit einheimischen Handwerker:innen zusammen, um deren Kenntnisse, Fähigkeiten und Fertigkeiten beim Bau und bei der Reparatur der Geräte mit lokal verfügbaren Materialien zu verbessern.

Aufgrund des wachsenden Interesses an der Bodengesundheit, an lokalen Lebensmitteln, an einer klimafreundlichen Landwirtschaft und an einer ökologisch sinnvollen Bewirtschaftung von landwirtschaftlichen Betrieben gewinnt die Zugtierhaltung in den USA wieder an Popularität. Für viele Zugtierhalter:innen haben ihre Tiere eine soziale und kulturelle Bedeutung und verkörpern einen Sinn für Gemeinschaft. Der geschickte Einsatz von Tierkraft ermöglicht es, anspruchsvolle Aufgaben wie Bodenbearbeitung, Aussaat, Unkrautbekämpfung, Holzeinschlag und Transport in angemessenem Umfang zu bewältigen. Die meisten landwirtschaftlichen Betriebe nutzen eine Mischung aus tierischer Zugkraft auf den Feldern und in den Wäldern und motorisierter Energie für den Materialtransport. Ein übergreifendes Thema ist, dass sich die Lebensstile der Anwender:innen auf einen geringeren Materialverbrauch und den Wunsch nach einem höheren persönlichen Niveau des globalen Wohlbefindens richten.

Résumé

Les animaux de trait fournissent la force de traction nécessaire pour labourer le sol, transporter le bois de chauffage et l'eau et acheminer les cultures du champ au marché. Ils fournissent de la viande, des peaux et d'autres sous-produits pour l'usage domestique et les revenus sur environ 250 millions d'hectares de terres dans les pays en développement du monde entier. Au Burkina Faso, en Afrique de l'Ouest, les agriculteurs qui ont accès à des bœufs sont des agriculteurs "privilégiés", et les 70 % qui n'utilisent que des outils manuels aspirent à avoir accès à des animaux de trait. Peu d'agriculteurs peuvent utiliser des tracteurs à roues de manière rentable, car les exploitations sont petites, les terres agricoles disponibles pour s'étendre sont rares et la main-d'œuvre agricole est abondante. La traction animale permet d'utiliser pleinement les ressources disponibles localement, améliorant ainsi leur efficacité et la résilience du système agricole. Dans notre travail d'amélioration des outils de labour de conservation du sol, plutôt que d'importer des technologies coûteuses, nous avons travaillé aux côtés d'artisans locaux pour améliorer leurs connaissances, leurs compétences et leurs capacités à construire et réparer l'équipement en utilisant des matériaux disponibles localement.

En raison de l'intérêt croissant pour la santé des sols, les aliments locaux, l'agriculture intelligente face au climat et la gestion agroécologique des fermes, la traction animale regagne en popularité aux États-Unis. Pour de nombreux praticiens, les animaux de trait ont une signification sociale et culturelle et incarnent un sens de la communauté. L'utilisation habile de la traction animale apporte une technologie réactive et à échelle appropriée pour des tâches exigeantes telles que le travail du sol, la plantation, le désherbage, l'abattage et le transport. La plupart des exploitations utilisent des sources d'énergie mixtes, la traction animale dans les champs et les forêts, et la motorisation pour la manutention. Un thème transversal est que les modes de vie des praticiens convergent vers une consommation matérielle moindre et un désir personnel d'un niveau plus élevé de bien-être global.

Resumen

Los animales de tiro proporcionan fuerza de tracción para labrar la tierra, transportar leña, agua y trasladar los cultivos del campo al mercado. Además proporcionan carne, pieles y otros subproductos para uso doméstico e ingresos en unos 250 millones de hectáreas de tierra en los países en desarrollo de todo el mundo. En Burkina Faso, en África Occidental, los agricultores que tienen acceso a los bueyes son agricultores "privilegiados", y el 70% que sólo utiliza herramientas manuales aspira a acceder a los animales de tiro. Pocos agricultores pueden utilizar tractores de ruedas de forma rentable porque las explotaciones son pequeñas, las tierras de cultivo para su expansión son escasas y la mano de obra agrícola es abundante. La tracción animal podría aprovechar al máximo los recursos disponibles localmente, mejorando su eficiencia y la resistencia del sistema agrícola. En nuestro trabajo en Burkina Faso trabajamos junto a los artesanos locales para mejorar las herramientas de labranza de conservación, en lugar de importar tecnologías costosas, a la vez favoreciendo la expansión de conocimientos, habilidades y destrezas de los artesanos en otros ambitos para construir y reparar el equipo utilizando materiales disponibles localmente.

Debido al creciente interés tanto por la salud del suelo como por la agricultura y la gestión ecológica de las explotaciones, la tracción animal está recuperando su popularidad en Estados Unidos. Para muchos profesionales de la tracción animal, los animales de tiro tienen un significado sociocultural y encarnan un sentido de comunidad. La aplicación hábil de la tracción animal aporta una tecnología sensible y de escala adecuada a tareas exigentes como la labranza, la siembra, la escarda, la tala y el transporte. La mayoría de las explotaciones agrícolas utilizan fuentes de energía mixtas, tracción animal en los campos y los bosques, y energía motorizada para la manipulación de materiales. Un tema transversal es que los estilos de vida de los practicantes convergen en torno a un menor consumo de materiales y un deseo de un mayor nivel personal de bienestar global.

Introduction

The inspiration for this paper was the interaction with attendees at the international conference, *the Global Draft animal Conference "Draft Animals in the Past, Present and Future",* held in May 2021 regarding the relevance and utility of animal traction. In the first part of the paper, I will share recent experience and observations in developing appropriate scale mechanization for animal traction for smallholder farmers in the West African nation of Burkina Faso. Here, animal traction is a luxury for those with access but remains an aspiration and is out of reach for most farmers. The second part of the paper focuses on draft animal use in the U.S.A. Tractorization has made draft animals nearly obsolete in the U.S.A. However, animal power is still an appropriate technology for many small-scale farmers. Five animal traction practitioners will explain why that is the case.

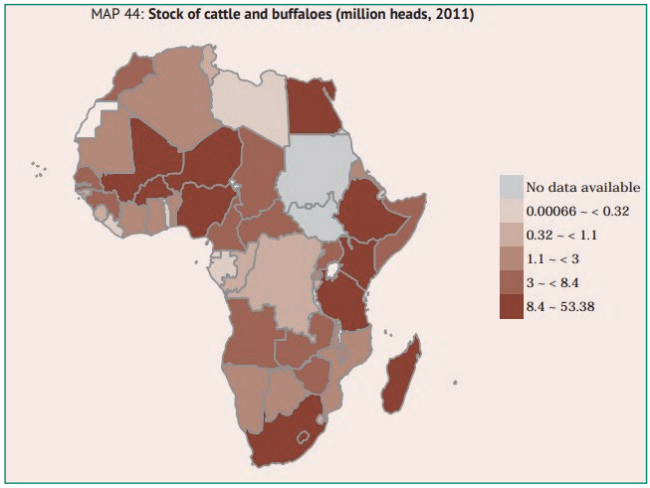

Figure 1 *– Distribution of cattle and buffalo in Africa in 2011*

Appropriate scale technology

Appropriate scale technology is the best fit or match-up between technology and the context of its use. Appropriate scale mechanization is technically, environmentally, economically, socially, and culturally correct for smallholder farmers. Worldwide, smallholder farmers strive to be financially sustainable and seek affordable technologies compatible with their economic and natural resource base. Animal power is relevant for many smallholder farmers because modern machinery is often inaccessible or unaffordable.

Draft animals provide tractive power to till the soil, transport firewood and water, and move crops from field to market. At the end of their lives, they provide meat, hides, and other byproducts for household use and income on about 250 million ha of land in developing countries worldwide. Hand labor is employed on about 125 million ha, while mechanized tractive power units cover nearly 104 million ha[1]. CIRAD[2] cites Jahnke[3], reporting about 170 million draft animals in Africa. About 86 % were cattle, along with donkeys, horses, mules, and camels. Figure one illustrates the stock of cattle and buffaloes.

1 L''Energie Cheval 2022.
2 CIRAD 1996.
3 Jahnke 1984.

Case study — Improving tools for animal traction in Burkina Faso

Figure 2 *– Young Burkinabé woman planting maize by hand with a 'daba'*

Our recent work in Burkina Faso, a small, landlocked country in West Africa, is an excellent example of where animal traction is the most appropriate technology. Ninety-two percent of the population of Burkina Faso is involved in agricultural pursuits[4]. Smallholder farmers typically work less than 3.5 hectares of land, mid-size farms are about 7 hectares, and large farms are 10 hectares. Forty-five percent of the farms have an income of less than $3 per day. Nearly the entire rural population relies on subsistence farming and lives in poverty.

Agricultural production is labor-intensive. Because the farms are small and farm income is low, animal traction and hand labor are widespread. Seventy percent of farmers do all fieldwork with hand tools. Nearly 29 % of smallholder farmers use oxen for tillage, yet planting and weeding are by hand. Farmers with access to oxen are 'privileged', and those using hand tools aspire to own or use draft animals. Animal traction is a significant technological advance for farmers accustomed to working solely with hand tools.

In the 1980s, Stuart Hill suggested three critical phases in the transition to sustainable agriculture 1) ef-

4 Beal et al. 2015.

ficiency, 2) substitution, and 3) redesign[5]. Efficiency is in targeted placement and tighter control of fertilizer and crop inputs to improve crop response. Substitution replaces existing technologies with more effective ones such as improved crop varieties or no-till cropping rather than inversion tillage. A redesign aims to deliver "*the optimum amount of ecosystem services to aid production while ensuring that agricultural production processes improve the ecosystem they depend on.*" A redesign can strengthen the agroecosystem by adding regenerative components.

Figure 3 *– Interaction and collaboration with local farmers is essential in understanding opportunities to redesign local farming systems*

Sustainable agriculture is not a specific technology; it is fundamentally a process of observing, learning, experimentation, and innovation. The redesign process develops social and human capital in deploying knowledge and the capacity for innovation to tackle landscape-scale problems. Interaction with local farmers and community members is essential in understanding opportunities to redesign local farming systems. Shared goals, values, and collaboration are critical in the redesign process. Farmers will fail to adopt even technically efficient and well-designed tools and implements if they are a poor match to local conditions[6].

At the outset of our work, we engaged farmers and other interested stakeholders in group settings to help us understand their resource constraints, needs, challenges, and opportunities. We challenged them with open-ended questions such as:

1) What is the local vision of smallholder farming systems that integrates all aspects of sustainability?
2) What forces (physical, biological, cultural, etc.) diminish the sustainability of local farming systems, and how can we offset them?
3) Which aspects of the local farming systems are most important to retain if the overall objective is a sustainable balance of environmental, economic, and social issues?
4) How can animal traction benefit local farming systems and balance sustainability and social and gender equity?

The farm community's highest priorities for innovation were improved tools and implements for alleviating the physical and time burden of 1) land preparation, 2) planting, and 3) weed control.

Appropriate scale technologies must be accessible to smallholder farmers. Mechanization and mechanical skills are insufficient at the farm and village levels. The supply chain and infrastructure for timely access to replacement parts, services, and repairs for imported equipment is generally nonexistent. There is a need to develop the mechanical skills of farmers and local artisans to efficiently use animal power. Worldwide, where mechanization took hold, the process has been stepwise and incremental, resulting in less labor-intensive farming systems. In our experience, improving tools for animal traction is one of the best ways to improve the lives of poor farmers while sustaining the natural resource base.

Figure 4 *– Local artisans developed skills in building and repairing planters and other implements with local materials*

Mechanization substitutes capital for labor. Mechanization must be affordable and have clear benefits in the cropping system to compete with low-cost hand labor on small farms. The purchase of a new machine or implement represents a significant investment. Even small, locally produced implements costing under $500 are substantial investments beyond the reach of many farmers. As sources of tractive power, wheeled tractors and draft animals are largely interchangeable because farmers can quickly adapt implements like planters and cultivators to either power source. Unless a wheeled tractor brings new ground into cultivation that hand labor or animal power cannot, simply replacing animal power with a wheeled tractor on a fixed land area rarely produces a larger production volume.

Animal traction — the most appropriate technology

There are many benefits of animal traction. Using mixed or diverse power sources on the same farm is quite common. Donkeys are mainly for material transport, but small utility vehicles are common near urban areas. Oxen do most of the primary tillage. Even when oxen or a tractor tills the soil, planting and weeding are hand tasks. Farmers' hand-harvest maize, and custom threshers shell it in return for a percentage of the crop. Women mill and process millet by hand to satisfy texture and taste preferences for family consumption.

5 Pretty/Pervez Bharucha 2018.
6 Starkey 1988.

Figure 5 – Mixed power sources on the same farm are common. Women process millet by hand to satisfy texture and taste preferences

Most smallholder farmers suffer from chronic low income. Few farmers can use wheeled tractors profitably because farms are small, farmland for expansion is scarce, and farm labor is readily available. In many areas, roads resemble little more than wide footpaths. Access for wheeled vehicles is challenging and, at times, impossible. Even in adverse weather, draft animals can navigate narrow trails and rugged terrain. In wet fields, draft animals are less damaging to soil than wheeled tractors.

Cattle for draft work are plentiful. Cattle reproduce. Little cash outlay is needed to replace an ox if it becomes disabled. Motorized tractors depreciate and lose value as they age, and modern farm equipment requires significant repair and maintenance costs. Fuel is expensive and subject to unpredictable swings in price. Reliance on mechanized power increases on-farm risk because farming communities lack the mechanical skills and support infrastructure to access replacement parts, repair breakdowns, and ensure timely field operations.

Animal traction makes full use of locally available resources, enhancing their efficiency and the resilience of the farming system. The value of an ox appreciates as it grows and matures, so farmers can sell an ox for more than they paid for it. The training of young draft animals receive increases their value, and draft animals increase in value as they mature and gain weight. The sale of mature cattle is an essential source of farm income that mitigates economic risk for the farm family.

A production system, not a simple technology

Figure 6 – Local artisans are collaborators actively involved in setting priorities, evaluating alternatives, and sharing work results

Figure 7 – Rather than importing expensive technologies, we worked alongside local artisans to enhance their knowledge, skills, and abilities to build and repair equipment using locally available materials

Figure 8 *– Strip-tillage builds soil health by conserving soil moisture, reducing tillage intensity, and retaining a protective crop residue on the soil surface*

Our approach to redesign farming systems is agro-ecological – a production system, not a simple technology. Machines and draft animals are part of a broader system where ecological and social benefits are valued and sought after. Our goal is to offer flexible options compatible with the local economic, social, and environmental conditions and enhance the farming system's efficiency and resilience. Our approach is participatory. Local farmers and artisans are collaborators actively involved in setting priorities, evaluating alternatives, and sharing the work results. Participatory development enhances farmers' capacity to learn about farms and resources.

Over-cultivation and over-grazing have degraded soils in Burkina Faso. Crop yield response to inorganic, commercial fertilizers is diminishing, and research has shown substantial yield benefits from combining inorganic fertilizers with organic nutrient sources such as manure and compost. Reclaiming and building soil fertility is a concern widely shared by smallholder farmers. Integrating crops and livestock on the farm returns organic matter to the soil and cycles crop nutrients through cropping.

Re-integrating crop and livestock systems is an opportunity to restore degraded soil and reclaim soil health. Livestock-based cropping systems improve soil fertility and crop yield by cycling nutrients from manure, compost, and cover crops. Forage crops extend the crop rotation and provide a vegetative cover to prevent soil loss. A 450 kg ox produces about 25 kg of manure per day—more than 270 kg of nitrogen and 180kg of phosphorus and other essential crop nutrients annually. Sustainable cropping practices minimize soil disturbance, maintain a protective vegetative or residue cover on the soil surface, and add organic inputs from manure, compost, and cover crops.

Local artisans, local materials, local solutions

There is a lack of affordable and accessible animal-drawn conservation tillage tools in Burkina Faso. The tools and implements need to be inexpensive, rugged, and functional, and built and repaired with local knowledge and

materials. The scope of our conservation tillage work encompassed the cropping system: an animal-drawn in-line ripper to reduce tillage intensity, improve water infiltration, and conserve protective crop residues; a planter to reduce the drudgery of hand planting; and a low-crown, low-pitch sweep cultivator to improve weed control. Rather than importing expensive technologies, we worked alongside local artisans to enhance their knowledge, skills, and abilities to build and repair the equipment using locally available materials. Local artisans and blacksmiths live among the farmers, understand their needs, and have the skills to develop and improve their tools.

In an adaptive management process, we built and evaluated a set of technologies compatible with the local economic, social, and environmental conditions. We redesigned an animal-drawn planter introduced decades earlier but widely rejected by local farmers because of the high cost and poor performance. We reduced the cost of the planter by 50 % by replacing an expensive imported spiral bevel gear drive with an open spur gear drive built on-site by local blacksmiths. We had made mold-injected seed plates for maize, sorghum, millet, and cowpea and an innovative furrow opener to place the seed at the correct depth. Locally built, concave discs well suited for clearing crop residue without plugging replaced the high crown furrow closers on the old-style planter. Finally, we reduced the press-wheel width by 50% to provide localized pressure to firm the soil in the narrow seedbed created by the in-line ripper. The refined planter's average implement draft was 20 kilogram-force (kgf), a manageable load for even a single donkey.

Figure 9 *– The implement draft dropped from 90 kgf with the moldboard plough to 45 kgf with the strip tiller, easing the burden on the local small-framed oxen*

Strip tillage builds soil health by conserving soil moisture, reducing tillage intensity, and retaining a protective crop residue on the soil surface. The strip-tiller tilled a narrow band of soil about 20 cm wide and 15 cm deep. It reduced the need for intensive full-width plowing or disking. We designed an open web steel truss to replace an expensive cast iron main beam, built a novel packer/crumbler to level, and firm the seedbed (***Figure 8***). The implement draft dropped from 90 kgf with a moldboard plow to less than 45 kgf with a strip-tiller, easing the burden on the local small-framed oxen and replacing full-width tillage with strip-tillage reduced by half the time in the field to prepare the soil for planting. By building the local artisans' and blacksmiths' mechanical and technical capabilities, we guarantee that farmers have local access to skilled and cost-effective labor for repair, maintenance, and ongoing innovation.

A mechanical advantage enables a biological advantage

The mechanical advantage of the planter enabled a biological advantage for the maize crop. The planter placed the seeds at a constant depth and consistent spacing. Seeds germinated faster and emerged at a uniform rate. Additionally, there was little need to replant, often required when hand seeding because of a low emergence rate. Side-by-side grain yield comparisons in farmer fields revealed an advantage from machine planting ranging from 50 % to 150 % compared to hand planting. Much of the yield increase was due to reduced seed loss to birds. Birds can easily find and consume hand planted seed, but they could not steal the machine-planted seed because they could not find it!

Agroecological concepts ground our approach to farming systems redesign. Evaluation is technical but viewed in social, cultural, and economic contexts. After one or two seasons of use, a group of women commented on the time and laborsaving impact of the animal-drawn planter on their lives. They noted that a family of three with a team of oxen could accomplish the work of a hand-planting crew of 15-20 laborers. The women used the time saved with the planter to perform other domestic tasks such as cooking, fetching water, child-care, and going to the market[7]. They could divert time from subsistence farming and household chores to income-generating activities such as processing shea butter or cashew nuts. Income from their off-farm enterprise funded children's schooling, food, and clothing. In addition, they saved money for unexpected expenses such as medical care and other family emergencies.

Figure 10 *– Time saved with the planter allowed women to divert time from subsistence farming and household chores to income-generating activities such as processing shea butter or cashew nuts*

Animal traction makes full use of locally available resources and enhances their efficiency and the resilience of the farming system. The benefits of animal traction and appropriate scale mechanization and the social process-

7 Harrigan/Jones 2020.

es that give rise to them are linked. Animal-drawn planter design benefits include efficient and effective planting with improved grain yield and farm income. The process benefits include greater affordability, accessibility, and repairability. Importantly, gender benefits accrue to the household through time and labor savings for women farmers and enhance entrepreneurial skills.

In recent years, the Food and Agriculture Organization of the United Nations (F.A.O.) has revisited the importance of working animals on the health and well-being of households in developing nations, particularly in the realms of agriculture, gender, food security, and rural development[8]. Working animals improve farm productivity by providing draft and transport power, milk, meat, hides, and other byproducts. Many smallholder farmers do not have access to mechanized power, so draft animals are central to their daily lives. There is a growing awareness of the need to raise the status and well-being of working animals worldwide, particularly in developing countries. Areas of concern include better veterinary care, animal nutrition and welfare, a need to reclaim skills in training draft animals, and the importance of indigenous knowledge in developing appropriate scale mechanization. There is a need to create and promote networking opportunities to nurture discussion and exchange of technical knowledge, engage a broader scope of stakeholders, and develop guidelines for best practices.

Draft animal power in the U.S.A.

Compared to Africa, where farm income was constrained because land for expansion was scarce and labor was abundant, the conditions in the U.S.A. were very different. In the 1800s, mechanization and technological change progressed in the context of limited labor and plentiful land[9]. With ample land for expansion, the lack of available labor limited farm production. Motorized tractors displaced nearly all working draft animals in the first half of the twentieth century. The transition from animal power to wheeled tractors and other agricultural machinery allowed farmers to increase the land area under production and produce a greater crop volume. Farm machinery investments steadily increased as the yields and profitability of farming increased due to these new mechanized technologies. The new machines allowed farmers to save time and labor, producing a greater volume of crops on a larger land area. The laborsaving devices developed as U.S. farms grew in size "*were typically built by local blacksmiths who lived among farm people, understood their needs, repaired their hand tools, and loved to tinker with tools, equipment, and machines*"[10].)

In many areas of the U.S., farms are small, and land for expansion is scarce or unaffordable. With the growing interest in sustainable development, soil health, local foods, mitigating climate change, protecting the environment, and ecologically sound farm management, animal traction is gaining popularity. Motorized draft power is locally available to these farms but not preferred for many tasks. Most farms use mixed-power sources; animal traction for field and forest and motorized power for material handling. A skilled application of animal power brings responsive and appropriate scale technology to demanding tasks such as tillage, planting, weeding, logging, transportation, and other chores. For many draft animal practitioners, draft animals have social and cultural significance and embody a sense of community. The animals are well integrated within the agricultural system and used efficiently and effectively within the local context.

The inspiration and rationale for applying animal power on farms in the U.S.A. vary from tasks and geographic location. I have invited five draft animal practitioners to explain how animal power contributes to their work and social environment. Long-term impacts will result from nurturing the social process whereby farmers take ownership of their development and the deliberate application of a living power source. A cross-cutting theme is that their lifestyles converge around lower material consumption, natural resource regeneration, and desire for a higher personal level of global well-being.

Carl Russell, Earthwise Farm and Forest, Bethel, Vermont, U.S.A.

Carl B. Russell and his wife, Lisa McCrory, own and operate Earthwise Farm and Forest in Bethel, VT. They raise organic vegetables and grass-fed livestock, use draft animals for logging and fieldwork, and offer workshops on skills for sustainable livelihoods.

Figure 11 *– Draft animal power is well integrated into the farming system at Earthwise Farm and Forest*

In 1986, at age 26, I bought a workhorse and started logging in our woods and for other landowners as part of my forestry business. There were several motivating factors behind this decision. Ecologically, draft animals reduced reliance on petroleum; economically, it reduced the costs of equipment purchase and maintenance. I valued the relationship with the animal through husbandry and work performance.

Over the last 36 years, I have worked horses and oxen in the woods and on the small farm built by my wife and me. The use of draft animals is a primary principle on our farm, using them for work in gardens, hayfields, and forests.

8 FAO 2014.
9 Cochrane 1993.
10 Ibd.

Working animals' performance rate often does not yield large financial gains because it takes a lot of work to work with animals.

From training/conditioning animals to repairing/building equipment, preparing the work site, felling trees, organizing gardens, and attaining related skills, once the animals are applied to a task, one has put in many hours and spent a lot of personal energy. While these realities can easily be seen as costly, they are also the source of significant personal reward – the aspect of working animals that substantiates the craft.

One of my strategies for using draft animals most effectively in our operations has been to engineer the scale of work to reduce their role to the most appropriate tasks. Our land-use systems that require motive power are purposefully limited to a scale that fits our animals' time and energy constraints and capabilities and affordable associated equipment.

Figure 12 *– Carl maximizes profit by keeping costs within the capabilities of animal-based production rather than through increased mechanical production to cover higher costs*

Farming system examples include; rotational grazing, feeding livestock outdoors during winter, and reducing the need to store, manage, and spread manure by orchestrating pasture systems that deposit nutrients as an ongoing process. We garden with semi-permanent raised beds within the scale and scope of animal power and human labor. With draft animal power, equipment and machinery costs are minimal, reducing the need for high volume production to support high fixed and operating costs.

We maximize profit by keeping costs within the capabilities of animal-based production rather than through increased mechanical production to cover higher costs. These basic principles allow for a greater personal reward through quality craft and husbandry, augmenting the admittedly lower overall income. This qualitative approach to personal compensation provides a level of profitability that justifies our reliance on living power that machinery cannot deliver.

Stephen Leslie, Cedar Mountain Farm, Hartland, Vermont, U.S.A.

Stephen Leslie is a co-owner of Cedar Mountain Farm and Cobb Hill Cheese, located in Hartland, VT. The farm produces milk, beef, mixed vegetables, and compost.

Figure 13 *– Cultivating garlic with a team of Fjords at Cedar Mountain Farm*

Over the last two decades at *Cedar Mountain Farm,* we developed systems for growing vegetables based on the methods we learned as apprentices on a biodynamic farm. The difference is we weaned ourselves off the wheeled tractor and achieved the goal of doing all the fieldwork, cultivation, and harvesting with our two teams of draft horses. Our dairy operation still relies on tractors; we feel that incorporating living horsepower into our vegetable production is a positive redundancy. They provide a truly "renewable" energy source and a regenerative component of the farming system.

Figure 14 *– Fjord power is the best fit for the farm, woodlot, and other tasks on Stephen Leslie's farm*

Economically, you would not purchase a 35 kW tractor to accomplish the workload of a 15 kW tractor. We chose to work with Norwegian Fjord horses because a full-sized

team of heavy draft horses would be overkill for the market garden scale we envisioned. The Fjord horse ranges in height from 13 to 15HH and typically weighs between 360 and 500 kg.

Before the last century, the Belgian and Percheron horses imported here were often crossed to lighter horses to produce a general-purpose farm horse. This suggests that the vintage equipment of that era is quite suitable for the smaller draft types such as the Fjord, Haflinger, Morgan, and drafts crossed with saddle horses. We have found the Fjords to be highly intelligent and trainable, nimble and careful with their steps, and possess great endurance and "try."

One of the compelling reasons for crossing the draft types to lighter horses was the economy of feeding the workhorse. A Belgian horse will require a bale of hay and some grain supplement in proportion to its daily workload. The typical Fjord is about half the size of a Belgian but only requires about one-quarter of the feed.

Our Fjord horses are the tractive power in our two-hectare market garden. Except for Amish-built forecarts and a plow, most of the equipment we use in the market garden is vintage early-to-mid-20th century horse-drawn implements. We use a 35 cm bottom walking plow, a 30 cm bottom riding plow, a 1.8-meter single-action disc, a three cubic meter single-axle ground-driven manure spreader, two sections of flex (pasture) harrow, a spring-tooth harrow, a riding cultivator, a 2.4-meter cultipacker, and a box-type lime spreader. We pull the spreaders, disc, and other harrows behind a standard Pioneer forecart (with the tongue length reduced from 3.9 to 3.0 meters). Come haying time, the Fjords also pull a no. 6 mower with a 1.5-meter bar, a Grimm tedder, and a New Holland side-delivery rake. A team of Fjords working within the scale of a two-ha garden can manage these implements without a problem.

The versatile Fjords also work well in the woodlot and make for a good riding horse, providing the farm family with a form of homegrown recreation and valuable for such farm tasks as checking fence lines or moving livestock groups.

Melvin Stoltzfus, Chestnut Feedery & Pet Store, Bradford, Pennsylvania, U.S.A.

Melvin L. Stoltzfus owns and operates a feed and pet store in Bradford, PA. He grew up on a farm in the middle of Pennsylvania and rubbed shoulders with the Amish as they were a primary customer base for his father's organic hay and grain. In the past, he sold portable Amish barns in his area and has used these connections to continue building relationships with them.

When the words 'Amish' and 'horse' come together, two pictures come to mind. One is a farmer in the field or woods using a draft horse. The other picture is a buggy going down the road with a smartly trotting horse in front. It is challenging to imagine the Amish people without horses and a slower way of life. Horses and the lack of motorized vehicles help keep the community close and significantly shape the Amish culture. They tend to set a slower pace and have a more deliberate and hands-on approach. The emphasis on farming and related craftsmanship gives their children something to do, responsibility, and a place in their culture.

This is not to say that farming with horses is a life of idyllic

Figure 15 *– An Amish-owned team of horses waits patiently while the logging crew breaks for lunch*

ease and a gentle pace; no, it is a physically demanding endeavor and requires situational awareness and common sense. Someone who can competently handle a young, energetic team of horses while spreading manure or mowing hay can rightfully feel a sense of accomplishment. Horses are used in any application that most people would use a car, tractor, or four-wheeler. Recently my father saw a young man riding a horse up a trail to an Amish barn. He was coming to help on the farm that day and took a back route to get there.

A question arises –are Amish farmers consummate horsemen and incredibly gifted people? I would say that, on average, this is not the case; they are aware of how to train their young people in this work and have a culture of learning on the job. There are common sense guides that they are careful to follow; for instance, you don't put your 11-year-old boy on a sulky plow with the new young team of Belgians. Youngsters train with older, more experienced teams on simple tasks. As the young man learns more about handling horses, he can graduate to handling less well-trained horses. If he is a gifted horse trainer and enjoys the work, he may even develop a sideline business of buying young horses in need of training, working them for a few years, and selling them for a profit after using them.

The horse has one more valuable deposit to make to the bottom line at the end of the day. His manure is used in the garden to grow excellent vegetables — a truly regenerative and multi-purposed creature.

Jim Slining, Director of Historical Collections and Exhibits, Tillers International, Scotts, Michigan U.S.A.

Jim is a lifelong student of historical technology. He combines experience with hand-tool technology and draft animal use with information revealed in historical artifacts to discover the context and circumstances optimal to their use.

***Figure 16** – Field-testing a three-row, ox-drawn planter at Tillers International*

Tillers International facilitates food security worldwide by helping smallholder farmers identify labor bottlenecks and design and initiate appropriate scale solutions to current challenges. Tillers International draws on historical examples of functional farming tools and systems and curates a collection of historic farm implements. In practice, we help communities locally produce affordable tools. Historically, human or animal-powered devices – simple though sophisticated – are easy to replicate without a significant investment in manufacturing facilities. Repair parts can be fashioned affordably by local artisans ensuring availability when the growing season demands.

***Figure 17** – Tillers International draws on historical examples of functional farming tools and implements to help local communities produce affordable tools*

In the 19th- and early 20th-century, when draft animals and hand tool labor were widespread, American farm tool designers were mindful of energy conservation. The physical architecture of tools from this era is instructive: lightweight yet durable, the weight placed to be an asset (over the bull/drive wheel, for instance); shape/size/angle of plow bottoms and tillage tools to match local soils, drive trains and bushings designed to minimize friction and energy use. Many clever design features are unnoticed when excess (machine) power is available. Existing wear marks tell the story of the tool's use and age. Perhaps how the device intersected with the soil or crop, evidence of operator (or draft animal) interaction, or lubrication use (or lack of). Repairs and redesign are evidence of on-the-job learning and a practical demonstration of physics principles. Such tangible evidence alludes to an intangible tool knowledge: the skills and abilities embodied in their use and application.

The work at Tillers International requires viewing history in context. We ask, "Under what social, economic, cultural, and natural environment was this ideal of agriculture accepted as best for that place and time"? Such awareness (which reveals opportunities for novel solutions) requires that reproduced tools of historical design (often paired with draft animal power) engage in real, physical work. Disuse safely preserves historical tools. Still, only the hands-on application of those tools maintains the skills to use them and appreciate their innate utility. We struggle to appreciate and understand the full context of past farming tasks without the skills and abilities forged in use. Tillers International and many other living history sites are uniquely capable of carrying out that mission.

As farm power and mechanization advanced in the U.S., agriculture established an efficient application of farm power that distributed limited physical and human

Figure 18 *– Kevin Cunningham uses oxen as the primary draft power source for his integrated crop and livestock farm*

resources evenly throughout the year. The need to conserve draft animals' energy reveals these systems' reality. Historical examples of these functional systems are crucial! One thread running through the *international conference 'Draft Animals in the Past, Present and Future'* was the widespread interest in adopting the West's "conventional" agriculture. Perhaps the most meaningful action would be to modernize the sophisticated historical farming systems and aptly apply them appropriately in our own back forty.

Kevin Cunningham, Shakefork Community Farm, Humbolt County, California, U.S.A.

Kevin Cunningham works 34 hectares along the Van Duzen River in Humboldt County, California, with his wife Melanie and son Clyde. They use draft oxen power on the 2.5 ha mixed vegetable garden and for moving a portable milking parlor and mobile chicken coops producing eggs and broiler chickens in the pastures. They integrate draft animal power into almost every part of the farm, including teaching farmer interns about regenerative agriculture.

We started in community farming as apprentices on a tractor-powered farm on the oxen-poor west coast of the U.S. My initial interest was in small grain production. Still, an assessment of the best use of the resource base made it clear that the most appropriate power source would be ox power. Most farm ground is rocky, unsuitable for cropping, but perfect for pasture. About 2.5 ha is suitable for cropping. We struck a deal with a local dairy farmer – four frozen chickens traded in exchange for four bull calves. After a few years of training the calves based on trial and error and with help from online networks such as the DAP-net Forum, we farm successfully with oxen – the primary draft power source for our market garden.

We transitioned from tractor to ox power, from conventional intensive tillage (plow, disk, fit, plant) to draft animal-appropriate, reduced tillage, raised beds. Most vegetable gardens in the region are smaller (one-quarter hectare or less) than our 2.5 ha plot. Ox power gives us longer and stronger arms--a level of tractive efficiency greater than human power or two-wheel tillers, but right-sized for our time and land base. Most of the implements used in the garden are modern, multi-purpose or vintage tools modified to achieve specific tasks. The goal is to have a one-person operation for the fieldwork.

Figure 19 *– The 2.5 ha tillable tract of mixed vegetables matches human and animal work and time constraints. Two covered greenhouses extend the growing season to a year-round operation*

We have a small cow-calf herd of Dexter cattle that we sell as grass-fed beef at the local farmers' market. We milk a few cows once per day for family and intern consumption and butter churning, with excess milk fed to pigs. The 2.5 ha tillable tract of mixed vegetables matches our human and animal working capabilities. Two covered greenhouses extend the growing season and supply the C.S.A. and local farmers' market year-round.

We have a mixed power-source farm. A small tractor is primarily for loader work--compost turning and materials handling. Two teams of oxen reside in a covered shelter. This assures frequent interaction for continuous ox training, and the manure and bedding collected in the shelter supply sufficient compost to feed the vegetable crops. The oxen have both physical and social roles on the farm. They are a unique attraction here in oxen-poor California, of great interest to farm visitors and at on-farm public engagement activities. The relationship and emotional connection with oxen are valued and have spillover effects on schoolchildren, visitors, customers, and social media. Many internship candidates are attracted to the unique opportunity to work with oxen, and they help draw a larger pool of candidates. At *Shakefork Community Farm*, oxen contribute to developing physical, human, and social capital and an integrated farming system with impacts that ripple at a landscape scale.

Draft animals have been rarely seen in the U.S.A. for almost seventy years. Yet the number of draft animal practitioners has increased as the interest in sustainable development, soil health, local foods, climate change mitigation, protecting the environment, and ecologically sound farm management gained popularity. For these draft animal practitioners, the intentional application of animal power is the most appropriate technology for their scale of farming. In working conditions, bystanders are often distracted from the work at hand by the power and elegance of working animals. However, for most agriculture, transport, and logging work, draft animals are simply the tractive unit providing motive power. The modern relevance is in the skillful application of living power to accomplish the tasks of tillage, planting, weeding, logging, etc.

Summary and Conclusions

In much of the developing world, on-farm mechanization is low. Draft animals provide tractive power to till the soil, transport firewood and water, and move crops from field to market. At the end of their lives, they provide meat, hides, and other byproducts for household use and income on about 250 million ha of land. Appropriate scale technology is the best fit, or match-up, between technology and the context in which it is used. Animal power is relevant for many smallholder farmers because modern machinery is often inaccessible or unaffordable. Animal traction is the most appropriate technology in Burkina Faso because farm income is low, labor is available, landholdings are small, and farmland is scarce for expansion. Mechanization must be affordable and have clear benefits in the cropping system to compete with low-cost hand labor on small farms. As sources of tractive power, wheeled tractors and draft animals are largely interchangeable because farmers can quickly adapt to implements like planters and cultivators to either power source. Few farmers can use wheeled tractors profitably because farms are small, farmland for expansion is scarce, and farm labor is readily available.

Largely replaced by tractors in the first half of the 20th century, draft animals have been rare in the U.S.A. for seventy years. Yet, farms are small in many areas, and land for expansion is scarce or unaffordable. Appropriate scale technology is the best fit or match-up between technology and the context in which it is used. With growing interest in sustainable development, soil health, local foods, climate change mitigation, environmental protection, and ecologically sound farm management, animal traction is gaining popularity. In working conditions, many observers are distracted from animal power work by the animals' novelty and elegance. Draft animals are simply providing motive power. Animal power brings responsive and appropriate scale technology to demanding tasks in agriculture, logging, transportation, and other jobs. The modern relevance is in the skillful application of animal power to accomplish demanding tasks with precision and efficiency.

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