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Agriculture: A Crop and Livestock Development System

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Abstract Agriculture is generally defined as the cultivation of crops, rearing of livestock and efficient use of production inputs. But the study uses the domestication of plant and animal resources as an introduction to agriculture and its sub-sectors. One aspect of domestication involves the relocation of a resource or their parts to human-controlled environments. The other aspect entails selection of individuals that manifest superior performance in maturation time, yields and other production traits. Series of selection pressures progressively drive a plant resource into becoming a crop and an animal resource into a livestock. The complete transformation of a resource into a domesticate results in the development of different sub-sectors of agriculture such as aquaculture, horticulture and silviculture. Lack of due attention to agriculture as a "crop and livestock development system" is partly responsible for food insecurity in developing societies.

Keywords Agriculture sub-sectors, Crop development, Resource domestication, Livestock development

1. Introduction

The production of valuable products and its organisation has been changing since the onset of the "Neolithic Revolution". This new form of production, which gradually replaced the exploitation of natural resources, may have been triggered by changes in climatic conditions, distribution pattern of food organisms and human population size [1, 2]. In the course of its gradual development, agriculture became a form of production that involves the establishment of human-controlled environments, invention of production units and practice of cultural methods. As a result, agriculture is associated solely with the cultivation of crops in fields or plantations, rearing of livestock in production pens or integration of different production units [3-6]. Agricultural production initially satisfied the food requirements of households but evolved into a form that meets the demand of communities and industries. As a form of production that depends on the use of inputs, the scope of agriculture may be expanded to include the efficient use of production inputs [7, 8].

The evolution of agriculture, from its simple to modern form, contributes to the development of human societies. Production of food products encouraged the ancients who were wanderers to embrace the sedentary lifestyle as well as facilitated the growth of trade through exchange of different farm products [2, 9]. Even more, the effect of surplus production in agrarian societies is novel as it freed some individuals to express other creative abilities such as writing and wood carving. Nevertheless, developing societies are often confronted with challenges in the process of organising agriculture into a form that can meet their growing requirement for food and raw materials. In most cases, there is a dearth of knowledge concerning the inherent nature of agriculture as a development system. This inadequacy finds expression in frequent changes in policy, frequent changes in institutional arrangements for agricultural research and instability in research governance [10-12].

There is, therefore, a need to understand the nature of agriculture as a development system. Domestication provides a means to a better understanding of agriculture since it is an attempt to secure the supply of plant and animal products [13, 14]. For this reason, the present study explores the transformation of a resource into a crop or livestock as an introduction to agriculture.

2. Resource Domestication: An Overview

Some biotic components of the environment are of direct benefit to humans. The utility value of several plants and animals makes each one of them a resource [13, 14].

A plant resource is a potential candidate for domestication. Valued plants are often transferred from their natural habitat to artificial environments. Seeds of rubber tree (*Hevea brasiliensis*) were collected from the Amazonian forest, nursed into seedlings in a botanical garden before their transfer to Southeast (SE) Asia [15, 16]. In SE Asia, generations of garden-grown rubber seedlings flourished into extensive plantations across the region. Like the case of rubber, relocated seedlings oil palm (*Elaeis guineensis*) and their generations manifest faster growth rate in artificial environments due to favourable climatic conditions. In more

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specific terms, individuals that were selected from field-grown dura populations produced higher yields when compared to previous generations and their semi-wild counterparts [17-20]. Even more, thick-shelled dura populations when crossed with the best of shell-less pisifera populations produced a thin-shelled fruit type also known as tenera [21]. The tenera yields more oil, given its reduced shell thickness and increased mesocarp size, making it the preferred planting materials in major oil palm projects. In this way, the transformation of the oil palm into a crop demonstrates the main aspects of Plant Resource Domestication (PRD), namely; relocation to human-controlled environments and selection of desired production traits. These main aspects of PRD are evident in all crops including rice (*Oryza sativa*) [22-24] and macadamia (*Macadamia integrifoIia*) [25, 26].

A valued animal is also a potential candidate for domestication. Common carp (*Cyprinus carpio*) was introduced into reservoirs from the Danube River and their successive generations flourished into present day cultured carp [27, 28]. Likewise, quails (*Coturnix japanicus*) were captured from the wild and transferred to confined conditions [29, 30]. Interestingly, selection for body weight and other production traits in captive populations produced better performances [31-33].

Domestication therefore facilitates better expression of production traits in a resource. The relocation of oil palm, to human-controlled environments and the improvements of its production traits, has reduced the age at maturity to about 2 years and increased yield to 24-32 tonnes per hectare in well managed plantations [20, 34]. Likewise, artificial selection in plantation-grown rubber tree increased latex yield from 400 pounds per acre in the earliest rubber plantings to over 3500 pounds per acre in modern selected clones [16, 35]. Similar improvements accompany the domestication of red jungle fowl (*Gallus gallus*) when its body weight (< 300g) is compared to those of improved meat breeds of domestic chicken (>1200g) within the same period [36, 37]. Selection for milk yield has improved the production of milk in cattle given the differences in performance between local breeds (< 900kg) and pure breeds (> 2000kg) within the same period [38, 39].

3. Resource Domestication & the Sub-sectors of Agriculture

The transformation of a resource into a crop or livestock initiates and expands a sector of agriculture. The development of aquaculture species is directly responsible for the advancement of aquaculture as a production unit in agriculture [27, 40, 41]. Horticulture, silviculture and other sections of agriculture owe their origin and expansion to the domestication of a resource [13, 14]. Several other plant resources have already been transformed into crops while relatively few animal resources are used as livestock (Table 1).

Table 1. Selected resources and their crop or livestock equivalent

PLANT RESOURCES [13]				
Wild Plant	Genus	Species Estimate	Wild Progenitor	Cutivated Species
Apple	*Malus*	above 27	*M. sieversii*	*M. domestica*
Potato	*Solanum*	206-232	*Solanum brevicaule* complex	7 species; *S.tuberosum* (globally)
Rice	*Oryza*	21	*O. breviligulata* *O.nivara/* *O. rufipogon*	*O. glaberrima* *O. sativa*
Rubber	*Hevea*	9	*H.brasiliensis*	*H.brasiliensis*
FISH RESOURCES [27, 40, 41]				
Wild Fish	GENUS	Species Estimates	Wild Progenitor	Cultured Species
Carp	*Cyprinus*	1 3 sub-species	*Cyprinus c. carpio*	*Cyprinus c. carpio*
Tilapia	*Oreochromis*	1	*O. niloticus*	*O. niloticus*
ANIMAL RESOURCES [14]				
Wild Animal	Genus	Species Estimates	Wild Progenitor	Domestic Species
Auroch (Wild cattle)	*Bos*	1 3 sub-species	*B.p. primigenius +* *B.p.opisthonomous* *B.p. nomadicus*	*Bos Taurus* *Bos indicus*
Bezoar (Wild goat)	*Capra*	8-9	*C.a. aegagrus*	*C. a. hircus*
Mouflon (Wild sheep)	*Ovis*	6	*Ovis orientalis*	*Ovis aries*
Red Junge Fowl	*Gallus*	4	*Gallus gallus*	*G. domesticus*

A wild plant or animal may be transferred from its natural habitat to human-controlled environments, for the purpose of domestication, whenever it is adjudged to be of immense value. Some of the on-going Resource Domestication programmes include those of the quinoa [42, 43], African bush mango [44,-47], African catfish [48, 49] and cane rat [50-53].

3.1. Quinoa (Chenopodium quinoa)

The quinoa is a native South American plant with a long history of cultivation. Grains of quinoa contain a bitter substance, *saponin*, believed to be one of the major factors that has restricted its spread to other continents. More recently, selection for certain traits allowed the development of new varieties of quinoa with higher yields and saponin-free grains [42, 43]. These improvements are changing the status of this native South American crop to a crop of global importance [54, 55].

3.2. African Bush Mango (Irvingia gabonensis)

The African bush mango is a tree found in the rainforest of Africa. It is one of the trees that were recently subjected to the process of domestication because of its utility value [13]. The tree, which can now be propagated through vegetative methods, has been transferred onto fields [44, 45]. Field-grown bush mango attains maturity in about half the period of its wild counterpart [46, 47]. Even more, the selection of superior genotypes within populations of field-grown bush mango is expected to complete the process of its domestication.

3.3. African Catfish (Clarias gariepinus)

The African catfish is endemic to the rivers of Africa. Introduction of this catfish into controlled environments altered the seasonal pattern of its reproduction [48, 49, 56]. However, the chance of producing large quantities of fingerlings at any period of the year is low due to the production of few eggs. This challenge has been resolved through the administration of hormones (hypophysation) which aids the spawning of large quantity of eggs [48, 57]. In addition, pond-reared catfish accepts formulated diets, grows faster and attain maturity in about half the time taken by its wild counterpart [5, 49]. These positive signs encouraged initiatives that are aimed at transforming the African catfish into a complete aquatic livestock [58].

3.4. Cane Rat (Thryonomys swinderianus)

The cane rat is one of the animal resources in West and Central Africa. For this reason, the animal was transferred to human-controlled environments where it displayed faster growth rate and larger litter size [50, 51, 59]. There is a likelihood of transforming the cane rat into a livestock, through artificial selection, given the modest to high heritability values for growth and other production traits [50, 51].

Table 2. Selected crops, aquaculture species, livestock including varieties and breeds

CROP & SELECTED VARIETIES/ CULTIVAR/ CLONES	
Crop	Major varieties/ cultivars/ clones
Apple	*Malus domestica* Brown, Circassian, Gala, Red, Paide's Winter, Wealthy [60].
Potato	*Solanum tuberosum* Atahualpa, Nicola, Russet Burbank, Tubira, Vitelotte [61]
Rice	*Oryza sativa* Kimboka, Agora, Sookha Dhan 5, NSIC Rc 25, NSIC Rc 360 [62]
Rubber	*Hevea brasiliensis* GT l, Tjir, PB 86, PB 312, RRII 105 [35]
AQUACULTURE SPECIES & SELECTED STRAINS	
Cultured Species	Selected Strains
Carp	*Cyprinus carpio* Germany mirror, Jian, Lotus, Songpu, Scattered mirror [52]
Nile Tilapia	Hybrids of female *O.niloticus* and O. aureus, O. macrochir, O. mossambicus, O. urolepis hornorum, O. spilurus niger [53]
LIVESTOCK & SELECTED BREEDS	
Domestic Animal	Selected Trans-boundary Breeds
Cattle	*Bos Taurus & Bos indicus* Meat breeds: Aberdeen Angus, Braford, Braham, Dexter, Normande, Diary breeds: Ayrshire, Brown Swiss, Guernsey, Holstein, Jersey[63]
Goat	*C. a. hircus* Anglo-Nubian, Boar, Bengal, Murciana, West African Dwarf [63]
Sheep	Meat Breed: *Ovis aries* Bornu, Dorper, Masai, Nguni Wool Breed: *Ovis aries* Australian merino, Corriedale, Devon longwool, Quessant, Romey [63]
Chicken	Egg Breed: *Gallus domesticus* Australorp, Legbar, Minorca, Dual-purpose Breed: *Gallus domesticus* Bresse, NewHampshire, Plymouth rock. Meat Breed: *Gallus domesticus* Fayoumi, Dokki, Jersey Giant [63]

The on-going domestication of bush mango gives an insight into the origin of other fruit trees and by extension horticulture. In the same way, the progress made in the process of domesticating the African catfish, makes present the history of aquaculture species and advances in aquaculture. Accordingly, there is an expectation that the cane rat, which is currently undergoing domestication, is on its way to becoming a livestock. This expectation includes a further selection of cane rat into breeds just as other livestock have breeds (Table 2).

4. Resource Domestication as a Development Principle in Agriculture

Present domestication programmes and those of previous generations adopt similar procedures. Relocation of bush mango from the wild into field banks is similar to the introduction of oil palm into cultivated gardens [17, 19, 44, 46]. Likewise, the transfer of the African catfish from the rivers of Africa to artificial environments in Europe follows that same trend as the transportation of wild common carp from the Danube River into reservoirs [27, 28, 48, 49]. In the same way, the steps taken to improve production traits in cane rat is in line with those applied to other animal resources that were transformed into livestock [52, 53].

Relocation of a resource to human-controlled environments produces change in growth and production pattern. For instance, the bush mango grows for over a decade before the onset of maturity but its growth period is reduced to about 5 years when introduced into human-controlled environments [46, 47]. Like the bush mango, the growth period of a macadamia tree may extend up to two decades before maturity. However, nursery-grown seedlings take 4-6 years to mature after their transplantation onto cultivated fields [25, 26]. Similar effects of domestication on reproduction performance include those in African catfish and Japanese quail. Maturation of gonads in catfish is seasonal due to annual changes in water temperature, photoperiod and water levels. But the same gonads remain mature throughout the year in controlled environments where those factors are maintained at satisfactory levels [48, 49, 56]. Like in the African catfish, the laying of eggs by wild quails is a seasonal event but it is an almost daily exercise in human-controlled environments [30]. Generally, these achievements introduce the next phase of domestication, which is, artificial selection in established populations of a resource.

Artificial selection often results in organisms with superior production performances. For instance, cultivated rice is susceptible to the rice grassy stunt virus (RGSV) which decreases rice yield significantly but becomes resistant to the disease through selective breeding programs [22, 23]. Given the differences in body weights of red jungle fowl (< 300g) and that of improved meat breeds of chicken (> 2000g) of the same age [36, 37], artificial selection for body weight improved meat yield 5 to 10 times. Selection also improves milk production given the differences in performance of local breeds of cattle (< 900kg) and those of improved breeds (> 2300kg) within the same period [38, 39].

The discussion reveals that both crops and livestock are products of the domestication process. From this perspective, domestication is a principle that controls the transition of a plant resource into a crop, in the same way, as it transforms an animal resource into a livestock [13, 14]. Put differently, domestication transforms primitive resources into highly productive crops and livestock. At the advanced level of plant and animal development, there is a function-based specialization in domesticates: rubber is grown exclusively for latex, certain birds are reared for eggs while some cattle are raised for milk (Table 2). This is the pattern of crop and livestock development in all the domestication centres from those in Southeast Asia to those in the Andean region of South America.

5. Conclusions

In developing societies, the practice of agriculture is based mainly on the cultivation of crops and rearing of livestock. This narrow version neglects the role of agriculture as a crop and livestock development system. Not surprising, this narrow version of agriculture eventual proves to be ineffective in addressing the food and raw material needs of those societies for the following reasons: First, there is an under-utilization of available lands since most crops do not thrive in drought-prone areas and soils with high salt content. Next, yield is often low as the productivity of existing crops and livestock remains constant and may decline in extreme climatic conditions. Furthermore, crops and livestock are often prone to new diseases such as the rice grassy stunt virus (RGSV) and *dermatophilosis* in cattle, both of which negatively affect production output. Finally, the narrow version of agriculture lacks the capacity to diversify its crop and livestock base. To overcome these limitations, agriculture may have to be organised in such a way that it includes the development of new crops and livestock as well as the improvement of existing ones into novel varieties and breeds. For instance, the development of salt-tolerant varieties of rice expands land area that may be used for rice cultivation, the artificial selection of high-yielding rice varieties increases the yield of rice per hectare while RGSV-resistant varieties prevents the loss of rice yield in a large scale. From this position, a society's quest for security in food and raw materials would be achieved when agriculture is also viewed as a Crop and Livestock Development System.

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