

Review Article

Resource Domestication: An Introduction to Biodiversity and Wildlife in Agriculture

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Abstract: Biodiversity and Wildlife are relatively recent concepts in Agriculture. However, the meaning of each concept remains to be clearly distinguished from similar concept in Natural Resource Conservation. The concepts of Biodiversity and Wildlife in Agriculture may be better understood when explored from the perspective of Resource Domestication. Relocation of a resource from its natural habitat into human-controlled environments represents an initial phase in the process of domestication. The final phase of Resource Domestication entails selection of desired production traits in established populations through breeding programs. A more complex relationship emerges in the course of transforming a wild plant into a crop or a wild animal into a livestock. The new relationship between a resource and its domestic form served as the framework for understanding Biodiversity and Wildlife in Agriculture.

Keywords: Agriculture, Biodiversity, Domestication, Wildlife

1. Introduction

Resource Domestication is a complex interaction between humans and a valued organism. It involves the relocation of a resource from its natural habitat to artificial environments as demonstrated in the domestication of oil palm (*Elaeis guineensis*) [1-3], rubber (*Hevea brasiliensis*) [4, 5], common carp (*Cyprinus carpio*) [6, 7] and Japanese quail (*Coturnix japonicus*) [8, 9]. Domestication also entails artificial selection of preferred traits as revealed in oil palm yield improvement exercises [10-12], in the development of saponin-free quinoa seeds (*Chenopodium quinoa*) [13, 14] and selection of higher body weights in Japanese quail [15, 16]. Knowledge of Resource Domestication often provides satisfactory answers to a number of very important questions; questions such as those concerning the relationship between native Amazonian rubber trees and their plantation-grown counterpart [4, 5] or the differences in gonad maturation of wild African catfish (*Clarias gariepinus*) and their domestic form [17, 18].

The impact of Resource Domestication extends beyond its initial motivation. On the one hand, relocation of a resource

into human-controlled environments was an expression of a desire to protect its dwindling supply occasioned by fluctuations in climatic conditions and expansion in local human populations [19-21]. On the other hand, artificial selection of traits explores the production potentials of a resource that is made visible through variations in individuals of the same population [10, 13, 14, 15]. The combined effect of these aspects of domestication is a transformation of primitive resources into highly productive cultivated plants or domestic animals. However, the impact of domestication also involves the evolution of new terms as a cultivated plant is referred to as a “crop” and a domestic animal a “livestock” after their partial or complete transformation [22, 23].

The use of terms such as “biodiversity” and “wildlife” is not uncommon in the field of agriculture. Wild plants are used in crop breeding programs [24-26], some wild animals are considered as livestock of the future while others have been identified as wild progenitors of modern livestock [27-37]. However, the current concept of Biodiversity or Wildlife does not sufficiently reflect the unique attribute of agriculture as a system that develops crops from wild plants and livestock from wild animals [22, 23]. More so, similar concepts in

Natural Resource Conservation accommodate undomesticated plants, flesh-eating birds and dangerous mammals which are not related to any crop or livestock [38, 39]. These broad concepts of Biodiversity and Wildlife blur the distinction that exists between conservation of natural resources and the development of crops or livestock through the process of domestication. It is, therefore, a necessity to understand the meaning of Biodiversity and Wildlife within the context of Resource Domestication in Agriculture.

2. Plants, Animals and Resources

Biotic components play important roles in processes that sustain the environment. Generally, plants serve as habitat for organisms, trap energy needed in an ecosystem but more importantly satisfy certain needs of society [22]. In the same way, animals are known to improve soil properties, aid pollination of flowers and dispersal of seeds. However, it is their utility value as adjudged by society that makes each one of them a resource [23]. But, a resource may exist only in a particular ecological zone or region. For instance, oil palm grows naturally in the rainforest of Africa, species of potato in the Andean region of South America and macadamia in Australian rainforest [1, 40, 41]. Likewise, species of wild cattle are endemic to parts of Asia, wild goat to Indian sub continent and wild sheep to Eurasia [42].

Resources seldom express their full production potential in their natural habitats. They often respond to interferences from extreme climatic conditions and biotic stress by manifesting slow growth, inconsistent fruiting pattern and low productivity [43-45]. For instance, a species of macadamia tree requires nearly two decades of growth to prepare for fruiting activities while the African bush mango grows for over a decade before the onset of maturity [46, 47]. Even more, production of fruits are often characterised by inconsistency and low yield in both cases. Like plant resources, animal resources such as wild Japanese quail and African catfish often display several attributes including late maturation and seasonal reproduction as responses to changes in environmental factors [9, 17]

The productivity of a resource is therefore generally low given the restrictions imposed by environmental factors. Estimate of fresh fruit bunch yield of wild and semi-wild oil palm trees range from 2 to 5 tonnes per hectare [1]. Similar low patterns of productivity characterise the yield of other plant resources such as rubber and macadamia [5, 41]. The quantity of products exploited from wild animals is equally low even though comprehensive data on the production performances between a resource and its domestic form are scarce. Nonetheless, the meat yield of red jungle fowl (JF) would have been less than those of its closest domestic relatives when the growth performance of JF (< 300g) is considered in relation to those of domestic chicken (>300g) within the same period [48, 49]. The differences in meat yield becomes vivid by comparing the production performance of JF (<300g) to those of improved breeds of chicken (>1200g) within the same period [48, 50].

Resource exploitation has consequences for the environment. Exploitation of a resource without appropriate management has led to a situation in which the population of some species is declining as indicated by the status of common ostrich (*Struthio camelus*) and wild goats (*Capra aegagrus*) [51]. More still, some resources are either threatened with extinction or have gone extinct as in the case of wild cattle (auroch). For these reasons, natural populations are increasingly being protected through scientific studies and establishment of National parks [32, 34, 52].

3. Resource Domestication

Domestication is essentially an indirect approach towards the conservation of a plant or an animal resource. It involves the introduction of a resource into human-controlled environments and afterwards selection of preferred production traits [22, 23].

Relocation of a resource and selection of its traits are the major aspects in domestication projects. Seedlings of bush mango were transferred from forest to farmlands even though the preservation of the tree on farmland is still a common practice [53]. Even more, seedlings of bush mango that were propagated using vegetative methods have been used in the establishment of field banks [54, 55]. In cultivated fields, bush mango attains maturity in about half the number of years required by its wild counterpart and produces fruits with superior indices [47, 56]. The improved performances of field-grown bush mango indicate the plant is responding to selection and also suggest the likelihood of further improvement through selection of superior genotypes. Similarly, cane rat was transferred from its natural habitat into experimental farms for the purpose of studying its growth and reproductive performances. In the course of domestication, the cane rat gradually accepted feeds during daytime, manifest higher body weight and produced larger litter size [57-59]. More still, moderate to high heritability values for body weight and other production traits including their correlations suggest that production performance of cane rat could be improved through artificial selection [60, 61].

Domestication therefore facilitates better trait expression in a resource. Artificial selection improved the yield of oil palm when fresh fruit bunch yield in wild/semi-wild populations (<5 tonnes/ha) is compared to that of well managed plantations (>20 tonnes/ha) [1, 62]. Likewise, there are improvements in productivity of animals due to effects of domestication. The meat yield of Japanese quail increased from about 100g in the earliest domesticates to about 300g in modern populations [15, 16]. Similarly, a comparison of the body weights of wild jungle fowl (<300g), native chicken ecotypes (>300g) and improved meat breeds of chicken (>1200g) within the same period [48-50], suggest meat yield of jungle fowl was improved over three times through artificial selection. In the same way, selection for milk yield in cattle increased production several times given the yield estimate of local breed (<900kg) and pure breed (>2000kg) within the same period [63]. This is a trend in milk production

of local cattle breed as increases in the degree of improvement leads to a corresponding increase in milk yield [64].

4. Resource Domestication, Biodiversity and Wildlife in Agriculture

The review above reveals that crops and livestock are products of Resource Domestication. Cultivated apple (*Malus domestica*) originated from a wild plant which is related to over 50 other *Malus* species [Table 1a; 65, 66]. Plantation-grown rubber, field-grown potato and cultivated

rice (including their varieties/clones) are the domestic forms of wild species with each having several close relatives [4, 5, 40, 65, 67-71]. Similarly, cultured common carp (*Cyprinus carpio*) is a domesticate of a wild form known to have several *Cyprinus* species as relatives [6, 7, 72]. Domestic goat (*Capra hircus*) and sheep (*Ovis aries*) descended from different wild progenitors but each progenitor belongs to a taxonomic group with several other species [33, 35, 36, 42]. The origin of domestic chicken (*Gallus domesticus*) can be traced to red jungle fowl (*Gallus gallus*), which shares common traits with other *Gallus* species [Table 1b; 30, 31, 73].

Table 1a. Selected Crops and their biodiversity (Wild flora & Varieties/ Cultivar/ Clones).

| Crop | Wild progenitor | Wildflora: Minimum Estimate & Selected Examples | Crop Diversity; Varieties / Clones: Selected Examples |
|--|---|---|--|
| Apple | | 54 species [65, 66] | Several hundred cultivars [68] |
| <i>Malus domestica</i> | <i>Malus sieversii</i> | <i>Malus angustifolia</i> , <i>M. asiatica</i> , <i>M. baccata</i> , <i>M. bracteata</i> , <i>M. chitralensis</i> , <i>M. coronaria</i> , <i>M. domestica</i> , <i>M. doumeri</i> , <i>M. floribunda</i> , <i>M. fusca</i> , <i>M. glabrata</i> , <i>M. hupehensis</i> , <i>M. ioensis</i> , <i>M. jinxianensis</i> , <i>M. kansuensis</i> , <i>M. M. lancifolia</i> , <i>M. melliana</i> , <i>M. micromalus</i> , <i>M. ombrophila</i> , <i>M. platycarpa</i> , <i>M. prunifolia</i> , <i>M. pumila</i> , <i>M. rockii</i> , <i>M. sieversii</i> , <i>M. spontanea</i> , <i>M. sylvestris</i> , <i>M. transitoria</i> , <i>M. toringoides</i> , <i>M. turkmenorum</i> , <i>M. yunnanensis</i> , <i>M. zumi</i> | <i>Malus domestica</i> Brown, Circassian, Coast, Gala, Lady, Red, Landsberger Reinette, Paide's Winter, Toko, Wealthy. |
| Potato | | 200 species [40, 65] | Several varieties [69] |
| <i>Solanum tuberosum</i> | Several species collective referred to as <i>Solanum brevicaulum</i> complex. | <i>Solanum albornozi</i> , <i>S. bulbocastanum</i> , <i>S. bukasovii</i> , <i>S. burtonii</i> , <i>S. cardiophyllum</i> , <i>S. chilliasense</i> , <i>S. commersonii</i> , <i>S. demissum</i> , <i>S. jamesii</i> , <i>S. inutifolium</i> , <i>S. paucijugum</i> , <i>S. phureja</i> , <i>S. pinnatisectum</i> , <i>S. regularifolium</i> , <i>S. stoloniferum</i> , <i>S. stenotomum</i> , <i>S. ternatum</i> , <i>S. tuberosum</i> | <i>Solanum tuberosum</i> Atahualpa, Nicola, Russet Burbank, Tubira, Vitelotte. |
| Rice | | 21 species [65, 67] | Several hundred varieties [70] |
| <i>Oryza glaberrima</i> <i>Oryza sativa</i> | <i>O. breviligulata</i> <i>O. nivara</i> / <i>O. rufipogon</i> | <i>Oryza australiensis</i> , <i>O. barthii</i> , <i>O. breviligulata</i> , <i>O. eichingeri</i> , <i>O. glaberrima</i> , <i>O. grandiglumis</i> , <i>O. latifolia</i> , <i>O. longiglumis</i> , <i>O. longistaminata</i> , <i>O. meridionalis</i> , <i>O. meyeriana</i> , <i>O. minuta</i> , <i>O. neocaledonica</i> , <i>O. nivara</i> , <i>O. officinalis</i> , <i>O. punctata</i> , <i>O. ridleyi</i> , <i>O. rufipogon</i> , <i>O. sativa</i> , <i>O. schlechteri</i> | <i>Oryza sativa</i> Kimboka, Agora, Sookha Dhan 5, NSIC 25, Nerica. |
| Rubber | | 10 species [4, 65] | Several clones [71] |
| <i>Hevea brasiliensis</i> | <i>Hevea brasiliensis</i> | <i>Hevea benthamiana</i> , <i>H. brasiliensis</i> , <i>H. camargoana</i> , <i>H. camporum</i> , <i>H. guianensis</i> , <i>H. microphylla</i> , <i>H. nitida</i> , <i>H. pauciflora</i> , <i>H. rigidifolia</i> , <i>H. spruceana</i> | GT 1, Tjir, PB 86, PB 260, PB 312, RRII 105, RRII 430 RRIM 600, RRIM 712, RRIC 100, RRIC130. |

Table 1b. Selected Livestock and their biodiversity (Wild fauna & breeds).

| Livestock | Wild Progenitor | Wild Fauna: Estimate & Examples | Livestock Diversity*: Estimate & Selected Examples |
|------------------------|--|---|--|
| Carp (Common) | | 22 (6 listed) [72] | Several [7] |
| <i>Cyprinus carpio</i> | <i>Cyprinus carpio</i> [6] | <i>Cyprinus acutidorsalis</i> <i>C. barbatus</i> , <i>C. carpio</i> , <i>C. micristius</i> , <i>C. rubrofusus</i> , <i>C. yunnanensis</i> | <i>Cyprinus carpio</i> Feng, Germany mirror, Hebao red, Heyuan, Huanghe, Jian, Lotus, Molong, Songhe, Songpu, Xingguo red, Xiangyun, Ying, Yue, Scattered mirror. |
| Cattle | | 5 [42] | 112 [74, 75] |
| <i>Bos taurus</i> | <i>B. p. primigenius</i> + <i>opisthonomus</i> | <i>Bos gaurus</i> , <i>B. javanicus</i> , <i>B. mutus</i> , <i>B. primigenius</i> , <i>B. sauveli</i> | Aberdeen Angus, Ayrshire, Braford, Brahman, Brown Swiss, Charolais, Chusco, Creole, Devon, Dexter, Galloway, Gascon, Gelbvieh, Goudali, Guernsey, Hereford, Holstein, Limousin, Lincoln Red, Muturu, Ndama, Normande, Red Angus, Senepol, Sokoto Gudali, White fulani. |
| <i>Bos indicus</i> | <i>B.p. nomadicus</i> [28, 29] | | |
| Chicken | | 4 [73] | 101 [74, 75] |

| Livestock | Wild Progenitor | Wild Fauna: Estimate & Examples | Livestock Diversity*: Estimate & Selected Examples |
|--------------------------|--------------------------------|---|---|
| <i>Gallus domesticus</i> | <i>Gallus gallus</i> [30, 31] | Sub species of <i>Gallus gallus bankiva</i> , <i>Jabouillei</i> , <i>murghi</i> , <i>spadiceus</i> <i>G. lafeyettei</i> <i>G. sonneratii</i> <i>G. varius</i> | Amrock, Australorp, Baladi Beheri, Bresse, Campine, Crevecoeur, Derbyshire Redcap, Dokki, Dresdener, Faverolles, Fayoumi, Gournay, Hamburgs, Hampshire, Jersey Giant, La Fleche, Minorca, NewHampshire, Orloff, Orpington, Plymouth Rock, Rhodebar, Sussex, Vorwerk, Warren, Wyandotte |
| Goat | | 8-9 [42] | 40 [74, 75] |
| <i>C. a. hircus</i> | <i>Capra aegagrus</i> [35, 36] | <i>C. aegagrus</i> <i>C. caucasica</i> <i>C. cylindricornis</i> <i>C. falconeri</i> <i>C. ibex</i> <i>C. nubiana</i> <i>C. pyrenaica</i> <i>C. sibirica</i> <i>C. walie</i> | Anglo-Nubian , Angora,, Barbari, Bengal, Berber, Boer, Dutch Pied, Gaddi, Granada, Kahalari, Kamori, Karachai, Maradi, Maure, Murciana, Nigerian Dwarf, Oberhasli, Peacock Goat, Poitou, Saanen, Sahelian, Somali, Toggenburg, Tswana, Verata. |
| Pig | | | 33 [74, 75] |
| <i>Sus s. domesticus</i> | <i>Sus scrofa</i> [37] | <i>Sus scrofa</i> [73] | Alentejana, American Berkshire, Berkshire, Chester White, Dalland, Duroc, Ghori, Haitian, Jersey Red, Lacombe, Large Black, Large White, Mangalitsa, Meishan, North Caucasus, Pelon, Pietrain, Saddleback, Seghers, Siska, Spotted, Tamworth, Turopolje, Welsh, Wessex Saddleback. |
| Sheep | | 6 [42] | 100 [74, 75] |
| <i>Ovis aries</i> | <i>Ovis orientalis</i> [33] | <i>O. ammon</i> <i>O. canadensis</i> <i>O. dalli</i> <i>O. orientalis</i> <i>O. nivicola</i> <i>O. vignei</i> | Australian Merino, Awassi, Blue Texel, Bond , British Milksheep, Chios, Coopworth, Corriedale, Devon Longwool, Dormer, Dorper, Dorset, Dorset Down, Drysdale, Finnsheep, North Ronaldsay, Quessant, Pool Merino, Polwarth, Polypay, Portland, Santa Cruz, Texel, Van Rooy, West African Dwarf, Zwartbles. |

*Trans-boundary Breeds/Hybrids

The development of a crop or livestock establishes new relationships. Cultivated rice as a special grain-producing plant plays the role of a food crop while other species of rice remain mere plants of an ecosystem. More still, cultivated rice responds to series of further selection for disease resistance and other traits resulting in the development of several varieties (Table 1a). The movement of rice from a mere plant or plant resource to a crop with varieties represents a process of rice development [22]. This development process establishes a new and complex relationship which consists of the wild progenitor of rice as well as other *oryza* species, earliest cultivated rice and its varieties. Put differently, cultivated rice and its varieties are the most advanced forms of rice while other *Oryza* species are wild flora, wild relatives or less developed forms. Cultivated rice, its varieties and wild flora when summed up represents the biodiversity of rice (Rice Biodiversity). In the same way, the biodiversity of other crops would be the sum of their earliest cultivated forms, varieties/clones and wild flora (Table 1a). Like crops, domestic chicken is an animal kept for a purpose while other *Gallus* species are mere birds or bird resource of an ecosystem. The development of domestic chicken establishes its wild fauna as less developed forms while domestic chicken and its

breeds are the most advanced in terms of productivity (Table 1b). Therefore, the constituents of chicken biodiversity are the earliest form of domestic chicken, its breeds and wild fauna. Similarly, the biodiversity of other livestock such as cattle, sheep and pig would be the sum of their individual wild fauna, earliest domestic form and breeds.

From Resource Domestication perspective, biodiversity is a specific concept that excludes all botanical entities that are not related to any particular crop or zoological entities that are unrelated to a known livestock. Accordingly, the biodiversity of rice excludes other members of the grass family (*Poaceae* or *Gramineae*). As a result, grasses such as spear grass (*Imperata cylindrica*) and other similar plants that are not directly related to any crop may not be categorised as part of Biodiversity in Agriculture. Likewise, the biodiversity of cattle excludes all members of the family (*Bovinae*) except its wild fauna, domestic form and breeds. In other words, cattle-like animals like African buffalo (*Syncerus caffer*) which fatally attack humans or American bison (*Bison bison*) whose domestication has largely been unsuccessful, do not belong to Cattle Biodiversity. These organisms and others like African grey parrot (*Psittacus erithacus*) and mountain gorilla (*Gorilla beringei*) are considered part of biodiversity by Natural

Resource Conservation-based Organisations [38, 39]. Interestingly, a Resource Domestication-based concept of biodiversity alters the concept of Wildlife to that which revolves around wild flora of crops and wild fauna of livestock.

5. Conclusion

The use, of basic terms like crop or livestock, is an implicit acknowledgement of Resource Domestication in Agriculture. Development of crops and livestock from wild resources reveals that Biodiversity and Wildlife have their roots in Resource Domestication. However, Biodiversity and Wildlife are distinct concepts in Agriculture. Biodiversity expresses the sum of different development levels of a particular crop or livestock while Wildlife is a collective term for either wild flora of crops, wild fauna of livestock or wild forms of both crops and livestock.

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