CONTRIBUTIONS OF "RESOURCE RELOCATION" TO THE DEVELOPMENT OF AGRICULTURE

Uchola B. E.

*Faculty of Agriculture, Federal University, Dutsin-ma, PMB 5001, Katsina State, Nigeria
Corresponding author: benuchola@gmail.com; 0909 672 5518

ABSTRACT

This paper examines the contributions of "resource relocation" in the development of agriculture. Five (5) selected resources from each sub-sector of agriculture were examined based on the number of known species (species diversity) and those species that were transferred into artificial environments (relocated resources). With few exceptions, the number of plant and animal species relocated to artificial environments is low compared to the total number of known species. Resources that were relocated for the purpose of domestication account for between 2.5-16.67% of known species in crop agriculture, 2.63-60% in horticulture, 12.5-25% in livestock subsector and 5.0-25.71% in aquaculture. The practice of "resource relocation" continues to contribute to the development of agriculture through the preservation of valuable native organisms, their use for agricultural production and the establishment of agricultural ecosystems.

Keywords: Agriculture, Agroecosystems, Biodiversity, Domestication.

INTRODUCTION

Relocation of wild plants and animals plays a central role in the development of agriculture. It is the beginning of a domestication process that results in crops and livestock (Kerr 1903, Zeven 1972, Schultes 1984; Khush 1997; Janick 2005). In this way, resource relocation indicates that production of desired products from the wild can be progressively increased and sustained through their relocation into artificial environments. Indeed, experience has shown that relocation of a plant resource engenders the production of its products to the satisfaction of society while at the same time diminishing the relevance of gathering as a method of production.

A similar experience defines the supply of animal products in contemporary society where animal exploitation (hunting) is of little importance when compared to the production systems borne out of the initial relocation of native animals adjudged to be of value or a resource.

The switch from a production system driven by the exploitation of wild resources to that which starts with the relocation of a resource is a very complex subject. Nevertheless, resource relocation as a phase in the domestication process is generally accepted as a response to alterations in climatic conditions, distribution of food organisms and human population (Blumler 1992; Diamond 2002). This response, which may be viewed as the earliest desire to use food resource in a sustainable manner, begins with the relocation of valued organisms from their natural habitats to human-controlled environments (Kerr 1903, Zeven 1972, Ajayi and Tewe 1980; Schultes 1984, 1993; Onadeko and Amubode 2002; Ataga and von der Vossen, 2007; Chang et al 2009). In addition, the chemical properties of a potential crop or livestock and its profitability as a farm product are now important factors as indicated in the recent evaluations of *Moringa oleifera* (Alikwe and Omotosho 2013, Animashaun and Toye, 2013).

The aforementioned investigations focus on the relocation of specific category of native resources from their natural habitat to artificial environments where they make their transition into the cultured state. More recent studies present resource relocation as an ecological aspect in the process of transforming native plants into crops and native animals into livestock (Uchola 2015a, b). However, there is a need to highlight the contributions of resource relocation to the development of the aquaculture, crop, horticulture, and livestock sub-sectors of agriculture. Such emphasis would reveal what the different sub-sectors of agriculture have in common in terms of development as well as provide insights into the “General Principles of Agriculture” which might be useful for training purposes. The study therefore examines relevant literatures with a view to understanding the contributions of resource relocation to the development of agriculture.

METHODOLOGY

The study covers the main sub-sectors of agriculture namely; crop agriculture, horticulture, livestock agriculture and aquaculture. Special attention was given to 5 selected resources in each sub-sector. The selected resources for each sub-sector are as follows: carrot, groundnut, maize, potato and rice for crop agriculture; gmelina, macadamia, mango, rubber and oil palm for

horticulture; bezoar (wild goat), jungle fowl (wild chicken), mouflon (wild sheep), wild cattle and wild pig for livestock agriculture; African catfish, American catfish, carp, tilapia and trout for aquaculture.

Sources of data: carrot (Saenz Lain, 1981; The Plant list 2013), groundnut (Seijo et al., 2007, The Plant List 2013); maize (Matsuoka et al. 2002; The Plant list 2013); potato (Hijmans and Spooner, 2001; Spooner et al., 2007); rice (Khush 1997; The Plant List 2013); gmelina (Orwa et al. 2009; The Plant List 2013), macadamia (Hardner et al., 2009; The Plant List 2013); mango (Mukherjee, 1953; The Plant List, 2013); rubber (Schultes 1984, The Plant List 2013); oil palm (Ataga and von der Vossen, 2007, The Plant List 2013); bezoar (FAO, 2007; IUCN, 2015); jungle fowl(FAO, 2007; IUCN, 2015) ; mouflon(FAO, 2007; IUCN, 2015) ; wild cattle(FAO, 2007; IUCN, 2015) ; wild pig(FAO, 2007; IUCN, 2015) ; African catfish (Na-Nakorn and Brummett 2009; Froese and Pauly, 2015); American catfish (Dunham and Smitherman 1984; Froese and Pauly, 2015); Carp (Balon, 2004; Froese and Pauly, 2015); Tilapia (Eknath and Hulata, 2009; Froese and Pauly, 2015); Trout (Solar, 2009; Froese and Pauly, 2015).

The examination focused generally on the natural distribution of each resource. Specifically, the study examines the number of species of a given resource that were relocated to artificial environments in relation to the known estimate of its species. The relationship between species diversity within a resource and those relocated to artificial environments are presented in ratio and percentage.

RESULTS

Crop agriculture and Horticulture

Relocations of resources range from 2.50 – 16.67% in crop agriculture and 2.63 – 60% (excluding oil palm) in horticulture (Table 1). Four species of potato; *Solanum brevicuale, S. ajanhuiri, S. curtilobum* and *S. juzepczukii*, were relocated to fields out of the 100 wild species representing 4 % relocation of potato resource for cultivation purposes. The ratio of species diversity to the number of carrot resource relocated is 40:1 representing 2.5% relocation of carrot species, 25:1 for groundnut representing 4% groundnut species relocation, and 6:1 for maize representing 16.67% of maize species relocation. Two species of rice *Oryza nivara* and *O.*

breviligulata were relocated to fields out of the 21 known species representing 9.5% relocation of rice species for cultivation purpose. The result shows a relocation of gmelina resources to be 2.63%, macadamia 60%, mango 10% and rubber 10%. The only exception is oil palm whose two species *Elaeis guineensis* and *E. oleifera* were both transferred to artificial environments representing a 100% relocation of the resource.

Table 1: Percentage of relocated resource in the crop and horticulture sub-sectors

Subsector	**Plant**	**Estimate of wild species**	***Estimate of relocated species**	**Wild species : relocated resource (ratio)**	**Resource relocation (%)**
Crop agriculture	Carrot	40	1	40:1	2.50
	Maize	6	1	6:1	16.67
	Groundnut	25	1	25:1	4
	Potato	100	4	25:1	4
	Rice	21	2	10.5:1	9.52
Horticulture	Gmelina	38	1	38:1	2.63
	Macadamia	5	3	5:3	60
	Mango	10	1	10:1	10
	Oil palm	2	2	1:1	100
	Rubber	10	1	10:1	10

Source: survey data, 2017

*Excluding sub-species. Carrot, *Daucus carota*; Maize, *Zea mays*; Groundnut, *Arachis monticola*; Potato, *Solanum brevicuale, S. ajanhuiri, S. curtilobum* and *S. juzepczukii*; Rice, *Oryza nivara* and *O. breviligulata;* Gmelina, Gmelina arborea; Macadamia, *Macadamia integrifolia*, *M. ternifolia*, and *M. tetraphylla*, Mango, *Mangifera indica*; Oil palm, *Elaeis guineensis* and *E. oleifera*, Rubber, *Hevea brazenlensis*.

+ Not exact. Only to emphasize that relocation of seeds, seedlings or some plants leaves the estimate unchanged.

++ includes silviculture.

Livestock agriculture and Aquaculture

Relocation of resources range from 12.50 – 25% (excluding wild pig) in livestock agriculture and 2.9 – 20% in aquaculture (Table 2). One species of bezoar (wild goat), *Capra aegagrus*, is preferred to the other 7 species representing 12.5% relocation of wild goat resource. One species of jungle fowl, *Gallus gallus*, is the preferred species from among the 4 known jungle fowl species. The ratio of species diversity to the number of relocated jungle fowl resource is 4:1 representing 25% fowl resource relocation. The preferred species of wild sheep, *Ovis orientalis*, is one of the 6 known species of the animal representing 16.67% relocation of sheep resource. One species of wild cattle, *Bos primigenius*, was the preferred candidate for domestication out of the 5 known species representing 20% relocation of cattle resource. One species of African catfish *Clarias gariepinus, one* species of American catfish *Ictalurus punctatus* and one species of carp *Cyprinus carpio,* are the major fish species from their respective category to be relocated to artificial environments. Others are 9 species of tilapia (Oreochromis) *Oreochromis niloticus* plus 8 other species and one species of trout *Oncorhynchus mykiss*. The result shows a relocation of African catfish resource to be 2.90%, carp 4.55%, American catfish 20%, tilapia 25.71% and trout 8.33%.

Table 2: Percentage of relocated resource in Livestock and Aquaculture sub-sectors

Subsector	Animal/ fish	Estimate of wild species	*Estimate of relocated species	Wild species : relocated resource (ratio)	Resource relocation (%)
Livestock agriculture	Bezoar	8	1	8:1	12.50
	Jungle fowl	4	1	4:1	25
	Mouflon	6	1	6:1	16.67
	Wild cattle	5	1	5:1	20
	Wild pig	1	1	1:1	100
Aquaculture	African catfish	35	1	35:1	2.9
	American catfish (Ictalurus)	10	2	5:1	20
	Carp (cyprinus)	22	1	22:1	4.55
	Tilapia (Orechromis)	35	9	35:9	25.71
	Trout (Oncorhynchus)	12	1	12:1	8.33

Source: Survey data, 2017

*Excluding sub-species. Bezoar, *Capra aegagrus*; Jungle fowl, *Gallus gallus*; Mouflon, *Ovis orientalis*; Wild cattle, *Bos primigenius*; Wild pig, *Sus scrofa*; African catfish, *Clarias gariepinus*; American catfish, *Ictalurus punctatus*; Carp, *Cyprinus carpio*; Tilapia (Orechromis), *O. aureus*, *O. esculentus, O. jipe, O. leucostictus*, *O. macrochir*, *O. mossambicus*, *O. niloticus*, *O. spilurus*, *O. urolepis* ; Trout (Oncorhynchus), *O. mykiss*

+ Not exact. Only to emphasize that relocation of some animals or fishes leaves the estimate unchanged.

++ genus of fishes: African catfish (*Clarias*), American catfish (*Ictalurus)*, Carp (*Cyprinus*), Tilapia (*Orechromis*), Trout (*Oncorhynchus)*

DISCUSSION

Crop agriculture and Horticulture

The resources that were transferred into artificial environments are often natives of a given region and relatively few. Natural populations of different species exist: carrots in Europe and the

Mediterranean, maize in Central America, potato in the Andes region of South America and rice around the river plains of Asia and West Africa (Saenz Lain, 1981; Khush 1997; Matsuoka et al. 2002; Hijmans and Spooner, 2001; The plant list, 2013). A number of native tree populations such as gmelina, macadamia, mango, oil palm, and rubber grow across or in specific regions of Africa, Asia, Australia and South America (Schultes 1984; Ataga and von der Vonssen, 2007; Hardner *et al.,* 2009; Orwa *et al.,* 2009; The plantlist 2013). The value of relocation for selected plant resources in crop agriculture range from 2.5-9.5% excluding maize whose double digit value of 16.67% falls outside the trend. The value in horticulture is 2.69 – 60% excluding oil palm whose 100% value is abnormal. Generally, the value is relatively low when compared to the number of wild species of each plant. Majority of wild plant species are either without valuable products and when present are of low quality as revealed in rubber tree: 7 species of rubber tree have latex of very poor quality, 2 species (*Hevea benthamiana and H. guianensis*) of modest quality and 1 species (*Hevea brazenlensis*) of very high quality (Schultes, 1984; 1993). This explains why *H. brazilensis* and few other wild plant resources were relocated to artificial environments. Generally, these relocations express of a desire to secure the supply of plant products that were threatened either by climatic conditions and higher demand by the ever-increasing human population (Blumler, 1992; Diamond, 2002).

The relocation of plant resources into artificial environment involves the development of agricultural ecosystems, the onset of cultivation practices and an improvement in the production performance of native plants. It may be argued that clearance of natural vegetative to accommodate relocated plants continues afterwards in the form of weeding just as soil tillage develops into the practice of ploughing since the aim of these cultural practices are similar. Information on how cultural practices improved the production of native plants is scare but the recent transfer of trees provides insight into the most probable pattern. Generally, the pattern of growth and reproductive maturity of native plants are altered in fields where competition for sunlight, space, and nutrients is absent. For instance, some wild macadamia species grow for almost two decade before the onset of reproductive maturity but a two-year old nursey-grown seedling require less than 7 years to attain maturity in fields (Hardner et al., 2009, Neal et al 2010). Other trees such as oil palm and rubber display similar pattern of performance after their introduction into artificial environments (Zeven, 1972; Schultes, 1984, 1993; Ataga and von der vossen, 2007).

Livestock and Aquaculture

The bezoar (wild goat), mouflon (wild sheep), wild cattle and pig inhabit regions of the Middle East and the Indian subcontinents but the jungle fowl are most abundant in Southeast Asia (FAO, 2007; IUCN 2015). Natural populations of carp thrive in freshwater systems of Asia especially China, North American catfish in the United States, tilapia in Africa and Asia, trout in Europe and North America (Dunham and Smitherman 1984 ; Balon 2004; Eknath and Hulata 2009; Solar 2009). The relocation of a selected animal resource into artificial environments for livestock agriculture is 12.5 – 25% excluding pig whose value is not in accord with the trend and 2.9-25.71% for aquaculture. The value is higher in livestock agriculture when compared to aquaculture due to the presence of fewer species in large terrestrial animals. Generally, species of animals and fish are selected based on certain criteria such as non-aggressive response to humans, omnivorous feeding habit, adaptability to wide range of environmental conditions, promiscuous sexual behaviour (Hale, 1969; Price, 1999; Balon, 2004). Only few animals and fish species satisfy these criteria which explain why the number of resources relocated to artificial environments is relatively low compared to the number of known species.

The relocation of animal and fish resources into artificial environments involves the development of artificial ecosystems, the onset of husbandry practices and an improvement in production performances. It is most probably that the confinement of animals in enclosures and the introduction of fish species into reservoirs progressed into ranch for ruminants, cages for poultry and ponds for fishes. Information on how husbandry improved the production of native animal and fish species are scare but the recent transfer of some species provide clue to the pattern of improvement. Generally, the behaviours of animals and fish are transformed in artificial environments: the quick escape response and occasional biting habit of Syrian hamster progressively decrease in captive conditions while the socially aggressive guinea pig begins to display a more socio-positive behaviour towards member of the same population making it more dispose to courtship and sexual behaviours (Kunzl and Sacher, 1999; Krause and Schuler, 2010). These changes in captive small mammals are indicative of behavioural changes in captive wild goat, sheep and cattle. Seasonal mating and lying of few eggs in wild quail are gradually replaced by frequent copulations and production of many eggs in captivity (Chang *et al.,* 2009) which points to the changes in the behaviours of the jungle fowl after its transfer to artificial

environments. The seasonal production and release of eggs in African catfish is altered under hatchery conditions as the gonads remain mature throughout the year (Hogendoorn, 1979; Huisman and Richter, 1987). Likewise, the selected fish resources developed a certain bold attitude in captivity and accept artificial feeds as first displayed by the gold fish (Balon, 2004), replacing their quick escape response and refusal to accept feeds from humans.

CONCLUSION

The relocation of plant and animal resources from the wild into artificial environments is at the development foundations of agriculture. It is often accompanied by the biophysical modification of natural ecosystems as well as invention of cultural practices both of which subject native organisms to new selection pressures. Relocated resources respond to new selection pressures in human-controlled environments by manifesting early maturation, frequent reproduction activities and higher productivity. "Resource relocation" is a common denominator in the development of sub-sectors of agriculture which indicates that certain principles underline the development of agriculture. The following are considered the major contributions of resource relocation in the development of agriculture:

- Aid the preservation of native resources
- Promotes establishment of agricultural ecosystems and invention of cultural practices.
- Allows the exchange and use of native species for agricultural purposes.

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