Ecologically Based Rodent Management (EBRM): A Promising Approach to Resolving Conflict between Man and Rodent Pest Species in Nigerian Agro-ecosystem

Abstract

The rising population of human being and advancement in technology mark the advent of conflict between man and the lower vertebrate species counterpart notably rodent species. Meanwhile, these rodent species cannot be denied the right to live. So, with introduction of settled Agriculture, natural flora are removed and crops are introduced to create agro-ecosystem within which the biotic components continue to interact, but as pests because of their infringement on what human is producing for the sustenance of his population. This prompted man to wage war against the rodent pest species by using conventional rodent control via the use of synthetic pesticides which poses health and environmental risks.

Though accorded the pest status, these lower vertebrate species serve tremendous ecological roles in the ecosystem.In the light of this, EBRM has been considered as the way forward in the effective management of rodent pest population and is viewed as a strategy that is sustainable, economical, and minimally damaging to the environment. Therefore, this paper was aimed at reviewing ecologically based rodent management (EBRM) as a promising approach to resolving conflict between man and rodent pest species in Nigerian agro-ecosystem.

Keywords: Rising human population, settled agriculture, Conflict, Rodent species, ecologically based rodent management, promising approach to rodent management

1. Introduction

The word "Rodent" is a mammalian order derived from the Latin word called "*Rodere*" meaning to gnaw. Hence, the mammalian species that belong to the order Rodentia are characterized by constant gnawing. Rodents remain the most serious pests in Sub-Saharan African countries, Nigeria inclusive. They inflict damage to agricultural produce both in the field and in the store. They equally cause economic damage to non-food materials that belong to humans. As if the economic damages are not enough, they also serve as reservoir hosts/carriers of zoonoses (Kingdon *et al.*, 2013; Badmus and Olawuni, 2022). They are the most destructive vertebrate pests known to be very difficult to control by the resource-poor farmers partly due to the fact that they have little or no knowledge of the identification of the pestiferous rodent species (Makundi and Massawe, 2011). Of all rodent species, only about 5% have been implicated as pests causing economic damage to crops while other species play ecological roles by aiding soil mixing and aeration, and serving as prey-base for predatory vertebrates (Aplin *et al.*, 2003). Therefore, identification of rodent species of economic importance before embarking on control measures is

very crucial. Morphological identification may not give accurate and reliable information. So, molecular identification is used to complement the morphological identification so as to have accurate information about the pest species down to the species level.

Meanwhile, for effective management of rodents, some factors are very crucial for consideration – population management (requires understanding the biology and population dynamics of the rodent species), habitat management (involves understanding the ecology of the rodent species in relation to the abiotic and biotic components within their environment), and people management (which entails understanding the relationship of the rodent species to the activities of human) (Witmer, 2022). These factors form the basis of an environmentally friendly approach to rodent management known as Ecologically-based Rodent management (EBRM). EBRM approach to rodent management minimizes the use of chemical rodenticides in the control of rodents. One of the strategies used as part of EBRM is the use of an immunological method known as immunocontraception which seeks to lower the fertility of rodent pests thereby reducing the number of young produced and recruited into the population. A number of studies have been carried out on the use of immunocontraceptives which have recorded a lot of success but replication of such studies has not been done in Nigeria. Some of the studies include Nash *et al.*, (2004) on California Ground Squirrel, Gionfriddo *et al.*(2009) andMiller *et al.*(2000) on White-tailed Deer etc. Therefore, this paper was aimed at reviewing ecologically based rodent management (EBRM) as a promising approach to resolving conflict between man and rodent pest species in Nigerian agro-ecosystem.

2. Ecosystem and Vertebrate Pest in Agriculture

Ecosystem/biome is understood as the interaction between the biotic and abiotic components of the environment, all relating as a system. The populations of biotic component form the community complex, which includes microbes, animals (invertebrates and vertebrates) and plants (herbs, shrubs, trees and flowering plants). These organisms interact in an interrelated manner in the natural ecosystem. They all co-exist as components of God created natural environment. The physical, chemical and biological forces that constitute the natural ecosystem are in a dynamic, but well-balanced state. The forces are maintained by natural checks and balance from each component benefitting from the association and contributing its quota to

further the association. For example, in their natural and undisturbed habitats the lower vertebrate species (mostly rodents) serve as prey items to sustain populations of predators.

However, with introduction of settled Agriculture, natural flora are removed and crops are introduced to create agro-ecosystem within which the biotic components continue to interact, but as pests because of their infringement on what human is producing for the sustenance of his population (Conover, 2002). Agro-ecosystem is one of the most disturbed ecosystems as a result of ever-increasing human population which culminates to continuous cultivation and encroachment of the natural habitat of the biotic components of the natural ecosystem.

Among various pestiferous organisms, vertebrate pests are the least studied in Nigeria. To this end, there had been little information on the rodent species causing which damage, the degree of damage caused and the economic impact of such damage. Farmers could only list the crops damaged and not the amount of losses caused in terms of yield and revenue.Akande (1986) carried out the pre-harvest losses estimate in rice farms in Southwestern Nigeria and was reported to be 37% of the possible yield. Meanwhile, the rodent pest species was reported tohave caused aneconomic loss of about 5% of the yield.

Some of the detrimental effects of vertebrate pests include:

a. Antelopes, monkeys, cane rats, squirrels, small rats, mice, bush fowls, dove, pigeon, etc depredate lots of fruits, cash and food crops.
b. House rats (commensal rats) have caused tremendous loss to stored products in granaries, factories, commercial stores, and domestic pantries. For example, it has been reported that 100 brown rats (*Rattus norvegicus)* consume 25-30g of food per day and more than one metric tons of food per annum. If a standard poultry in Nigeria, as reported, has about 1000 rats in and around the premises, 250-300g of feed concentrate is lost daily and about 110kg is lost annually to rodents' depredation. The population of rats in the market place in Nigeria is put at 5000 per hectare because of the poor sanitary situation. This translates to food loss (including garbage) of up to 500metric tones per annum per market. The Asia is reported to lose up to 40 million tons of rice per annum to rats.
c. Commensal rats e.g. shrew, and snakes attack rabbits, eggs and chicken.
d. Rats and mice destroy manufactured goods, office equipment (including files, certificates etc), building structures and household appliances.

e. Telephone and electrical cables are attacked by house rats, causing disconnection and malfunctions in homes and offices. Sparks may result from exposure of electric cables and may lead to inferno and loss of valued properties. It was reported that 5 to 25% of fires of unknown origin on farm and homes are caused by rats (Witmer, 2022).
f. Diseases like dreadful bubonic plague, Lassa fever, pseudo tuberculosis, etc are transmitted to man by rats through deposition of ectoparasites (ticks and lice) on food, biting of sleeping children and adults and careless handling of carcasses of freshly killed rodents(Meerburg*et al*., 2009; Battersby, 2015).
g. Rodents attract snakes to live in and around human dwellings. Common snakes found on the field and around the houses are Gaboon viper (*Bitis gabonica*), Black cobra (*Maja melaoneua*), Brown snake (*Mehelyacrossi*), large African python (*Python regius*) etc.

Damages to Field Crops by some rodent pests

Some of the damage caused by the rodent pest species to some field crops and the culprit pests responsible for the damage are as highlighted below:

- African giant rats make holes on pod to depredate the Cocoa beans on the field
- Cane rats, giant rats, and Tree squirrel feed on fleshy oil palm fruits and also damage the oil palm seedlings
- Removal of newly sown and germinating seeds of groundnuts by Cane rats
- Removal of groundnut pods by ground squirrel
- Feeding on the soft sugar containing tissue of the internodes of Sugar cane by Cane rats
- Digging out of freshly sown and germinating seeds of Cerealsby Ground squirrel,
- Digging up and carting away of yam setts, and small tubers of cassava and yam by Giant rats

Damages to Stored Produce by rodent pests

Damages to stored produce are often caused by rodents. The damages are best appreciated by considering:

- Damages done to produce itself
- Damages done to containers, including plastics, baskets, sacks etc.

- Contamination of stored produce by faecal droppings. The cost of cleaning the produce of faecal droppings adds to the losses incurred from other damages.

Damages to livestock: Rodents mostly indicted are *Rattus rattus, Mastomysnatalensis, Crociduraflavescens.*

The types of damage may be direct attack or indirect attack. The indirect damage include:

a. Consumption of livestock feed
b. Contamination of livestock feed with urine and faecal droppings.
c. Damages to poultry and rabbitry house.
d. Transmission of diseases like Salmonellosis, leptospirosis etc.

The direct attack on livestock like rabbits and chicks could in form of

a. Decapitation of chicks by *Crociduraflavescens*.
b. Infliction of deep wounds on adult birds and rabbits.

3. Genesis of the conflict between man and rodent species

The rising population of human being and advancement in technology mark the advent of conflict between man and the lower vertebrate species counterpart. The human desires for food, fibre, clothing, shelter and other comforts of life increase tremendously, and the mode of life changed from pastoral gathering system to settled agriculture and had to carry out cultivation and series of constructions. In effect, man embarked on destruction of natural ecosystem to give room for his desired cultivation and construction (Mulungu *et al.*, 2010).

These activities of man disrupt the forces responsible for the stability of natural ecosystem. The disruption culminates in the deprivation of other animal components of the ecosystem their means of existence, thereby placing some hardships on them. Since these organisms have inalienable rights to existence that man could not terminate, they cling on to life by either changing their taste or entering into stiff competition with man, their main enemy. These organisms are mostly feeble, so they can only fight back by stealthily foraging the man's provision for his personal needs. Since they interfere with human interest (taking portions the creation that are supposed to be theirs but that have been forcefully taken up by man), they are termed pests (selfishness in the highest order). This is the basis of pest in Agriculture.

4. Beneficial ecological roles of lower vertebrate species outnumber their detrimental roles

Though accorded the pest status, these lower vertebrate species serve tremendous ecological roles in the ecosystem. They aid in soil mixing, aeration, and moisture retention; they release droppings which enhance nutrients and organic matter contents of soil; they serve as pollinating agents; they are agents of seed dispersal which assist in achieving plant diversity in the ecosystem; they serve as prey-base for many avian (hawk), reptile (snakes) and mammalian (fox) predators; they serve as source of animal protein; some of them are indicators of ecosystem health – a term known as environmental engineers. A notable burrowing rodent species called African giant rat (*Cricetomysgambianus*) is now trained to detect tuberculosis in the sputum of a patient as a novel diagnostic technology (Minion *et al.*, 2009). It is also used in the detection of landmines (Szatai, 2020). Also, in their herbivory activity, they deplete seeds of many useful plant species in the soil seed bank, which may bring about extinction of such plant species, and serve in the transmission of many zoonotic diseases, the most common here being the Lassa fever being transmitted by Lassa virus whose vector isNatal Multi-mammate mouse (*Mastomysnatalensis*) (Kingdon *et al.*, 2013).

Justifiably, of all the rodent species, only about 5 – 10% are reported to be pests. The remaining 90-95% play tremendous roles in ensuring effective ecosystem functioning in which human benefits a great deal (Aplin *et al.*, 2003). Continuous adoption of chemical warfare approach to resolve the human and lower vertebrate species conflict will wipe out non-target useful ones and deprive man the many benefits. Hence, resolving the conflict demands alternative and environment-friendly means of managing populations of lower vertebrate species in the ecosystem, which informs looking into the Ecologically Based Rodent Management.

In summary, some of the beneficial importance of rodents include the following:

a. Burrowing rodents dig tunnels in the soil. The tunnel improves the soil structure, aeration and moisture retention.
b. The granivores feed on seeds of weeds thereby reducing seed load in the soil seed bank.
c. The droppings of rodents enhance the organic matter content of the soil.
d. Some vertebrate pests are sources of cheap animal protein for households.
e. The killing and selling of the wild vertebrate pests, though may be illegal, provides employment opportunity for both the hunters and vendors of the meat.

f. Some rodents are included in the ethno-medical preparations for the folklore treatment of certain ailments e.g. *Crociduraflavescens* is included in ethno-medicine to treat convulsion in children in Yoruba land.
g. Rodents being mammal, serve as experimental animals to test new products meant for human use.

5. Peoples' perception about Vertebrate (Rodent) Pest Management

Common perception among the Nigerian farmers is that rodent pest species are very difficult to control. In fact, whenever some farmers cultivate, they always factor in a portion of the cultivated crops for rodent pest species (Singleton *et al.*, 2003). Meanwhile, these pest species know no boundary as they go about in search of their daily bread and shelter. In so doing, some gregarious species even depredate more than the portion allotted to them by the farmers. Farmers have adopted both non-chemical and chemical approaches (which may be non-lethal or lethal) to manage the population of rodent pests on crop fields and in stores (Makundi and Massawe, 2011). Non-chemical methods of rodent population management can either be used to achieve lethality or to prevent or exclude rodent species. Lethality of rodent pests can be achieved using snap trap/break-back trap, wire snare, leg-hold traps, pitfall trap, glueboard trap, etc (Odeyemi and Daramola, 2000; Ofuya and Lale, 2001; Aplin *et al.*, 2003). Rodent pests can be prevented or excluded from an area using rodent-proof materials (e.g. metal contraption), ultrasonic devices, frightening devices, wire-fencing, etc (Odeyemi and Daramola, 2000; Buckle and Smith, 2015). Non-lethal chemical methods are basically chemical repellent (odour-offensive chemicals) to repel rodent pest species from an area. Examples include the use of predator urine, peppermint oil, etc (Ofuya and Lale, 2001; Buckle and Smith, 2015). Lethal chemical methods are categorized into the use of non-anticoagulant (acute or fast-acting) rodenticides and anticoagulant (chronic or slow-acting) rodenticides (Endepols*et al.*, 2015).

A study carried out by Badmus and Ala (2020) reported that majority of the people in the study area in Nigeria adopt the use of synthetic rodenticides in the control of rodent species either in field situation or in the store. While chemical control is an integral part of rodent pest management, the use of synthetic rodenticides is usually taken as the last resort in Ecologically Based Rodent Management because of their attendant shortcomings (Chamber *et al.*, 1999;

Erhunmwunse*et al.*, 2012; Buckle and Smith, 2015). In effect, managing rodent pest under EBRM involves the use of non-chemical, non-lethal chemical, and rarely chemical methods.

6. Ecologically Based Rodent Management: The promising approach to rodent pest management

Ecologically Based Rodent Management (EBRM) is an Integrated Pest Management (IPM) for rodent pest management which involves minimizing the use of chemical rodenticides (Makundi and Massawe, 2011). It is considered as the way forward in the effective management of rodent pest population by keeping it below that which can inflict economic damage to agricultural crops. It is viewed as a strategy that is sustainable, economical, and minimally damaging to the environment (Makundi and Massawe, 2011).

Going forward, the adoption of the EBRM strategy in Nigeria will minimize the economic damage due to these rodent pest species, protect the non-target useful rodents and the environment. The EBRM as stated by Conover (2002) and Witmer (2022) is built on tripod which includes having understanding of:

i. the biology and population dynamics of the pest species (Population Management)
ii. the ecology of the pest species within its physical and biotic environment (Habitat Management)
iii. the relationships of the pest species to the activities of the humans (People Management)

i. Population management

This involves knowing the life history and dynamics of the rodent pest species to ensure effective decline in the rodent pest population in the field and store situations(Witmer, 2022). Some of the methods employed in managing rodent pest population include the following:

- Use of toxicants commonly called rodenticides, baits, fumigants, glue boards, and several trapping techniques (Witmer, 2018). Rodenticides (toxicants or poison baits) are poisonous chemicals used either as baits, dusts or water formulations to kill rats and mice or reduce their populations. There are two major groups of rodenticides which include non-anticoagulant and anticoagulant rodenticides. Non- anticoagulant rodenticides are also regarded as acute poisons. They are single dose baits or toxicants used for quick

rodent population reduction (Endepols*et al.*, 2015). Some examples of acute poisons include zinc phosphide, strychnine, bromethalin etc. The major advantage of using acute poisons is that it is often used in situations where anticoagulants cannot be safely set out over a long period of time. However, two major problems are often associated with use of non-anticoagulant toxicants which include development of bait shyness by rodents and increased hazard of secondary poisoning to non-target organisms particularly the scavengers (Chamber *et al*., 1999). Anticoagulants or chronic poisons are introduced to solve the problems of bait shyness development and secondary poisoning that acute poisons have. So, anticoagulants act mainly by lowering the rate at which prothrombin (a blood clotting factor) is secreted by the liver which in turn causes internal hemorrhage that eventually leads to the death of the animal. Anticoagulants come in various forms such as powders which are used as highway poisons, cereal-baits ready for use, concentrates only, weather-proof wax, block formulations or capsules. Examples of common anticoagulants include warfarin, brodifacoum, bromadiolone, flocoumafen, difethialoneetc (Endepols*et al.*, 2015; Witmer, 2018).

Some advantages of chronic poisons over acute poisons include the lack of bait shyness, their good palatability (acceptable taste) and availability of an effective and practical antidote.

- Trapping is another method of rodent population reduction. it is an effective method of control especially where infestation is very light or where few survivors of a poison treatment needs to be eliminated. There are four major types of trap which include single-capture live traps, single-capture kill traps and snares, multiple-capture live traps, and pitfall traps (Aplin *et al.*, 2003; Witmer, 2018).
- Glue board trapping technique can also be used. It is actually an alternative to traps and particularly helpful for catching mice (Odeyemi and Daramola, 2000; Ofuya and Lale, 2001). Glue boards are usually placed across runways of mice or where traps are normally placed. They should not be kept in dusty environment because dusts would normally affect the efficacy of the glue. In addition, moisture, temperature extremes and particles could affect their stickiness.

- Rats and mice can also be killed using fumigation method. The most commonly used fumigants are hydrogen phosphide, methyl bromide and carbon tetrachloride (Endepols *et al.*, 2015).

A relatively new rodent control method is fertility control**(**Jacoblinnert*et al*., 2021; Witmer, 2022). This requires that a palatable bait or liquid containing a drug/chemical is put in strategic places so as to either reduce or prevent the rodent from being able to breed successfully when consumed.Diazacon, nicarbazin, vinylcyclohexene, and triptolide are some of the chemicals having the potentials of cause reduced fertility in rodent (Witmer, 2019). One fertility control product, ContraPest is a notable product reported to have been recently registered by the United States Environmental Protection Agency (USEPA) which is effective against black rat and Norway rat (Siers *et al*., 2020). ContraPest contains vinylcyclohexene and triptolide as liquid formulation (Witmer and Raymond-Whish, 2021).

Another aspect of EBRM which has not gained popularity particularly in the developing countries is the consideration of some botanicals and/or their products capable of suppressing the reproduction of rodent pest species (Massei and Cowan, 2014). This approach reduces the number of young produced and recruited into the population and hence reduces the damage caused (Tran and Hinds, 2012; Bhakta *et al.*, 2019). The effects of the products on reproductive performance depend on the mechanism of action as to whether they may be reversible or permanent. These products may act by directly exerting their inhibitory effects on a specific process such as implantation, development of oocytes, and ovarian follicles (Tran and Hinds, 2012). It may indirectly affect a number of sites such as vagina, oviduct, and uterus within the reproductive tract of animals because of the changes in hormone synthesis and release by the hypothalamic–pituitary–gonadal (HPG) axis (Tran and Hinds, 2012; Massei and Cowan, 2014). Examples of such agents are the use of steroids, agonists and antagonists of gonadotrophin-releasing hormone (GnRH), immunocontraceptive vaccines, and natural plant extracts (Arawwawala*et al.*, 2010). It was revealed from the study conducted by Badmus and Alarape (2022) on the people's opinions about the performance of common rodent population control methods and the readiness of the people to embrace plant-based formulated diets as a method of rodent fertility control to reduce rodent pest population in Nigeria, that fertility control of rodent

using plant-based formulated diet was viewed as a promising method of rodent pest population control which would prevent the case of accidental poisoning and reduce emotional concern about chemical control methods. It was also opined that use of plant materials capable of reducing rodent fertility would be one of the environment-friendly alternatives to chemical rodenticides.

ii. Habitat management

Managing the habitat of the rodent pest species involves understanding the interaction of the pest species with the abiotic and biotic components that make up the environment of the particular pest species in order to have effective management. Non-lethal rodent control includehabitat management, both in the crop fields and surrounding vegetation. Those surrounding areas often provide cover and food for rodent year around, but also act as refugia for rodents after crops are harvested where they can survive until the next crop cycle begins (Witmer, 2022). After a crop harvest, crop land can be made less habitable to rodents by burning or otherwise removing plant stubble. Unfortunately, that can also result in increased soil erosion and/or water loss. The surrounding "refugia" areas can also be mowed or burned so that they are less supportive of rodents. Less palatable plants can be used on lands surrounding crop fields, such as endophytic grasses which contain a fungus unpalatable to herbivores (Witmer and Pipas, 2018). Arid and semi-arid lands generally do not support a lot of rodents, but when we irrigate those lands for crop production, we greatly increase their rodent carrying capacity (Witmer, 2022). Another way to modify habitats is to install raptor perches which can result in greater predation on rodents and other small mammals such as rabbits (Witmer *et al*., 2008).

- Rodent-proofing measures: this involves the use of physical barriers or mechanical proofing (exclusion), electrical barrier, frightening devices, and use of chemical repellents (Buckle and Smith, 2015).This method is aimed at ensuring that rodents do not gain access to building or shelter and food supplies. Freedom from rats and mice in buildings and other enclosures can only be guaranteed by proofing the premises against entry by these animals. New buildings and stores can be proofed more easily than existing structure and the incorporation of proofing devices into structures which are to be erected could considered to be desirable provision (Ofuya and Lale, 2001). Without

satisfactory proofing, the other control measures are virtually worthless in such circumstances. The use of exclusion/physical and electric barrier, in theory, means that rats and mice could be denied access to shelter, food, escape and nesting areas (Ofuya and Lale, 2001; Buckle and Smith, 2015). This is a very difficult task since it involves proofing of facilities and buildings in such a way that there would be no opening for rat and mice. However, in practice, house mice and young rats are known to pass through a 12mm and 14mm apertures respectively. Therefore, rodent exclusion would involve sealing off all holes larger than 6mm or ¼ inch (Ofuya and Lale, 2001). Rodent proofing should also be done with heavy materials that are not susceptible to gnawing. Galvanized containers, concrete mortars and heavy gauge hardware cloths could be used for this purpose. Electrical barriers are simple gadgets that could easily be used to exclude and enclose rats and other animals. They have the advantages of being effective in protecting stored foods against rodents and the ease of being moved about but their maintenance cost is high (Ofuya and Lale, 2001).

Rodents particularly mice are easily scared by unfamiliar sounds but they easily get used to such sounds and become fearless about them. High frequency sounds actually prevent free movement into a building or from one area to another. However, effectiveness is doubtful since the rats and mice can neither be killed nor prevent them from having access to farm, food stores or buildings. In addition, any ultrasound that could cause permanent physiological damage to rodents may likely cause damage to both humans and other animals too. Therefore, ultrasonic devices are not usually recommended as an effective scare device (Witmer, 2022).

- Repellents or odour offensive chemicals can be used to repel rodents. Naphthalene has been proved effective as a mouse repellent (Ofuya and Lale, 2001).Sulfurous odors from predator feces or urine can also be effective. Some rodent repellents in form of plant secondary metabolites are also promising in repelling or driving away the rodents (Hansen *et al.*, 2016). However, their effective practical application in crop fields over large areas is doubtful as rodents can adapt or get acclimatized to them, especially if hungry enough. Moreover, there could be issues such as flavor problems with human foods (Witmer, 2022).

iii. People management

This involves understanding the influence of land uses, management practices, and hriman activities on rodent populations (Witmer, 2007; Witmer, 2022).

- Environmental sanitation or hygiene: This is the orderly management and maintenance of a clean environment in and around the farms, stores, and warehouses. Good hygiene in and around premises and warehouses will reduce the cover for rodents and discourage their activity (Odeyemi and Daramola, 2000; Ofuya and Lale, 2001). This also includes a general improvement on personal hygiene, good housekeeping, proper post-harvest handling of food items and organic wastes. A high sanitation standard must be maintained at all times if the best result is to be achieved. The hiding places of rats and mice should not be disturbed during or just before treatment with rodenticides, fumigants or traps. Tidying up should be done as soon as treatment is completed (Odeyemi and Daramola, 2000; Ofuya and Lale, 2001). Hygiene methods should go hand-in-hand with measures designed to prevent rats and mice from getting into premises which are likely to become re-infested (Odeyemi and Daramola, 2000).
- Shifting cultivation combined with mono cropping tends to reduce rodent species diversity. The fallow phase also tends to reduce the population of available rodent species since the food availability may not be suitable for the various populations.In intensive cultivation with many crops being grown all year round, the rodent species diversity and population level are often very high.
- Timely planting, weeding and harvesting tend to keep the population of rodents, in terms of species diversity and magnitude, below havoc levels.
- Maintenance of clear gap between farm and bushes. This will reduce invasion of the farms by rodents from the bushes.
- Removal of plant debris from the farm edge and within the farms. This removes all possible hideouts for the rodents and therefore discourages incursion and multiplication of rodent on-farm.
- Timely detection of presence of rodents: These will ensure early control of rodent attack on crops, thus reducing rodent damage.

- Timing planting with alternative food source: timing planting of vulnerable crops so that the period of maturity may coincide with that of alternative food sources may reduce rodent pest attack.

Based on the above, the forefront of effective rodent population and damage management strategy under EBRM is habitat modification (Witmer, 2007; Witmer, 2022). All rodent species require food, water, and shelter for them to thrive successfully in any ecosystem. Removal of food source, water source, and/or shelter will certainly decimate the rodent population and therefore their damage. This is a common cultural practice but seemingly difficult among some people. Poor sanitation of the environment usually encourage rodent species to inhabit and establish themselves (Ofuya and Lale, 2001). Therefore, keeping the surrounding of the farm very tidy goes a long way in making such surrounding unconducive for the rodent pest species to thrive (Ofuya and Lale, 2001; Witmer, 2022).

Rodent species have high reproductive potential which partly accounts for their success in carrying out their damaging activities (Buckle and Smith, 2015), and an agro-ecosystem is never occupied by a single species.Therefore, it is expedient to continuously monitor the species diversity (which factors in the species richness and population of each species) so as to know the dominance level of the species occurring in the area. It is possible to have numerous rodent species in any given area, but that does not translate to all of them being the cause of the observed damage. The EBRM strategy seeks to identify culprit pests causing the damage among the numerous rodent species in an area. This will assist in designing an effective control strategy, to reduce complications of baiting and trapping and protect non-target rodent losses (Witmer, 2022).

It is strongly believed that if the three factors identified in the tripod above (Population Management, Habitat Management, and People Management) are integrated, effective management of rodent population and damages they caused to crops and production system will be achieved. This is an attempt of ensuring that economy and ecology are carefully balanced in the course of rodent pest management to achieve a landscape that is safe, protective and productive.

7. Conclusions

Adoption of EBRM in its whole form is going to solve the problem of rodent pests attack both in the store and field situations. Humans should always be objective in their approach in the management of rodent pest species as these species are not originally created as pests. Moreover, they have vital ecosystem services they render which humans immensely benefit from. So, they should adopt the approach of live and let live whenever they want to embark on rodent pest management.

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