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A Mathematical model to Study the Effect of Herdsmen/Farmers Crises on Agricultural and Economic Growth in Benue State, Nigeria

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ABSTRACT
We developed a mathematical model to assess the ill activities of herdsmen on the people of Ukum and Logo local government areas of Benue State. We evaluated the effect of security on the dynamics of herdsmen activities in Ukum and Logo which has been implicated in the spread of crises across the state. The resulting co-mingling of the people of these local governments which are at high risk does not only explain high prevalence of crises in Ukum/Logo and the subsequent spread of the menace in the whole state, but also points out the magnitude of the problem (killings, burning of houses and destruction of properties/produce and even grown crops) and the urgency of introducing effective security measures for the control/eradication of communal crises. Furthermore, results from our numerical experiments show that security could be a very effective measure to control/eradicate the unrest. However, proportion of those communities being secured must be sufficiently high, say 80% and above.
Keywords: Model, LAS, Stability, Crises, Security

INTRODUCTION
Grazing is a method of feeding in which a herbivore feeds on plants such as grasses, or other multicellular organisms such as algae. In agriculture, grazing is one method used whereby domestic livestock are used to convert grass and other forage into meat, milk and other products. Many small selective herbivores follow larger grazers, who skim off the highest, tough growth of plants, exposing tender shoots. For terrestrial animals, grazing is normally distinguished from browsing in that grazing is eating grass or forbs, and browsing is eating woody twigs and leaves from trees and shrubs. According to Concise Oxford Dictionary, Grazing differs from true predation because the organism being grazed upon is not generally killed. Grazing differs from parasitism as the two organisms live together in a constant state of physical externality (i.e. low intimacy) (Stilling, 1999). Water animals that feed for example on algae found on stones are called grazers-scrapers. Grazers-scrapers feed also on microorganisms and dead organic matter on various substrates, (Begon,etal. 1990)

The use of livestock grazing can be dated back to the Civil War. During this time, land ownership was not common, and ranchers grazed their cattle on the surrounding, often federal, land. Not having a permanent home, these cowboys would frequently graze an area down, and then continue on their way. More commonly, however, cattle were rotated between summer and winter ranges. Soon, the public saw how profitable cattle could be and many tried to get into the cattle business. With the appearance of free, unlimited grass and feed, the land became overcrowded and the forage rapidly depleted. Ranchers tried to put a stop to this by using barbed wire fences to barricade their land, water sources, and cattle. After failed attempts, the Taylor Grazing Act was enacted in 1934. This act was put into place to help regulate the use of public land for grazing purposes and allotted ranchers certain paddocks of land. Additionally, "fees collected for grazing livestock on public lands was returned to the appropriate grazing district to be used for range improvements"

(HPLLG, 2008). The Taylor Grazing Act helped to stabilize rancher's operations and allow them to continue raising their livestock.

Benefits of Grazing

In some habitats, appropriate levels of grazing may be effective in restoring or maintaining native grass and herb diversity in rangeland that has been disturbed by overgrazing, lack of grazing (such as by the removal of wild grazing animals), or by other human disturbance. Conservation grazing is the use of domestic livestock to manage such habitats, often to replicate the ecological effects of the wild relatives of livestock, or those of other species now absent or extinct. By utilizing grazing systems, livestock production has the potential to be maximized. "Approximately 85 percent of U.S. grazed lands are unsuitable for producing crops. Grazing animals on this land more than doubles the area that can be used to produce food. Cattle serve a valuable role in the ecosystem by converting the forages humans cannot consume into a nutrient-dense food" (Fact Sheet, 2008). Grazing occupies 26 percent of the Earth's terrestrial surface, while feed crop production requires about a third of all arable land. Expansion of grazing land for livestock is a key factor in deforestation, especially in Latin America: some 70 percent of previously forested land in the Amazon is used as pasture, and feed crops cover a large part of the reminder. About 70 percent of all grazing land in dry areas is considered degraded, mostly because of overgrazing, compaction and erosion attributable to livestock activity. Furthermore, the animal's urine and faeces "recycle nitrogen, phosphorus, potassium and other plant nutrients and return them to the soil"(NHO, 2008) It also acts as rations for insects and organisms found within the soil. These organisms according to NHO 2008, aid in carbon sequestration and water filtration; nutrients and organisms all of which are necessary for soil to be prosperous and capable for production. Darlymple (2008) opined that grazing helps to promote the growth of native plants and grasses. Often, these indigenous plants are not able to compete with the surrounding plants that utilize the majority of water and nutrients. By livestock grazing, the non-native grasses are controlled and the native plants can redevelop. As well as using grazing to increase plant growth, the actual hoof action of the livestock also promotes growth. The trampling helps to imbed the seeds into the soil so that the plants and grasses can continue to germinate, grazing can also allow for "accumulation of litter (horizontal residue)" helping to eliminate soil erosion. Soil erosion is important to minimize because with the soil erosion comes a loss of nutrients and the topsoil. All of which are important in the regeneration of vegetation.

Grazing in Nigeria

Nigerian livestock industry is largely dependent on natural vegetation. Although there vast hectrage of natural vegetation in the country they are not maximally utilized due to poor planning and conflicting government policies. It was estimated that there are over 40 million hectares of grazing land in Nigeria, out of which only 3 million hectares are specifically tagged as grazing reserves (Kemis, 1967; Adegbola, 1982). These grazing reserves are areas set aside primarily for livestock production and were established under the Northern Region Grazing Reserves Law of 1965 (Nuru, 1988). It was earlier recognized that over 90% of the nation's livestock (excluding pigs and poultry) are in the hand of transhumance and nomadic pastoralist, although there are growing number of settled livestock owners and agropastoralist (Calderbank, 1991). According to Ezeomah (1987), in the past, pastoralist did not make any serious effort to acquire lands largely because of their conservatism, independence and abundance of grazing lands. However, in recent years increased crop cultivation associated with other land needs due to the rapidly growing population has created serious pressure on many traditional grazing areas. These and other related problems have made the pastoralist to start seeking for the lands to settle for at least wet season.

Effects of Dwindling Pasture Resources on Pastoral Fulani

Most grazing reserves are situated on impoverished land, with little agronomic potential (Goldschmidt 1980). An inspection of the sites and edaphic properties shows that the grazing reserves have inferior fodder, consisting of low-protein *Andropogon, Brachiarria,* and *Loudetia*. For example, in Borno State, which has the largest population of livestock in Nigeria, there is hardly enough grass for year-round grazing. In the early dry-season, herds in this state browse on tree leaves, branches, and farm leftovers. At the climax of the dry-season, animals eat anything green, including their own faeces and the so-called poisonous grass (de St Croix 1945). The Fulani adapt to these shortages by using more farm residue or by grazing in urban areas. Productivity as low as 2,250 kg/ha has been reported on the grazing lands (Fricke 1979). Animals feeding on such herbage suffer hypo-proteinemia and subcutaneous oedema (Bekure 1983). While it is believed that the chronic scarcity of pasture is the primary cause of nomadic pastoralism, the same scarcity is causing the Fulani to take their herds to the uncontested forage in the outskirts of towns and large villages. Roaming cows, sheep, and goats scavenging around school playgrounds, golf courses, government residential areas, street shoulders, and railway sidings are a common sight in the cities. These beasts obstruct traffic flow, endanger street users, and accentuate urban congestion. In addition to annoying riders and drivers, animals litter the ground and bring flies and stench (Awogbade, 1980).

As development spills from the urban core to the rural hinterland, farmers escalate their incursions on the dry-season grazing land (*Hurumi*), the rainy-season grazing land (*Mashekari*), and the cattle-route (*Burtali*). These incursions prevent the government from acquiring large parcels of grazing land. The disappearance of natural grazing areas under the hoe, the fencing of farmyards, and the blocking of cattle-routes are causing more conflicts between the farmers and the grazers. To stop farmers' encroachment on the grazing land and the ensuing conflicts, the authorities in 1965 passed the Grazing Reserve Law, which carved out some grounds for the exclusive use of pastoral Fulani. This law became the first major attempt of the government to incorporate the interests of the grazers in national development. The law, at least in the books, protects herders against intimidation and deprivation by sedentary cultivators, cattle-ranchers, and commercial intruders. The evolution of grazing reserves in Nigeria, discussed below, shows a history of problems in the grazing land development. The lack of legal validation or legislation on stock routes, for example, makes blocking the routes a non-punishable offence. The absence of enforceable penalties discourages herders from suing farmers who extend farms into the cattle thoroughfare, (Awogbade, 1980).

The Nature of Grazing in Benue State

Benue State like most of the states in Nigeria are no longer safe with the presence of Fulani herdsmen activities around them. The incessant clashes between the Fulani herdsmen and farmers resulting to crises where lives are killed, houses/properties burnt, food stuff/ crops on field being destroyed in the recent time in the state poses a great danger to food security, agricultural and economic growth of the state owing to the fact that Benue State is the food basket of the nation. This menace if not checked, poses danger of hunger not only to Benue but the entire nation. Attacks by Fulani herdsmen in the North-central Nigerian state of Benue has led to the killing of at least escalated 1, 269 persons, investigations by PREMIUM TIMES (2016) have shown. Out of the 23 local government areas in the state, the rampaging herdsmen have invaded and occupied 14 and may invade the remaining nine unless urgent measures are taken to curb the menace, authorities said. Our findings, confirmed by residents, security officials and the state governor, also showed that in the North-east Senatorial District of the state, the herdsmen have invaded Katsina-Ala, Kwande, Logo, Ukum; leaving out Vandeikya, Konshisha and Ushongo. In Benue North-east Senatorial District, the killer herdsmen have attacked all the other local government councils except Gboko.In Benue North-west Senatorial District the of the state, council areas invaded and occupied by the killer herdsmen include Guma, Gwer-West, Gwer-East, Buruku, Tarka and Makurdi local government councils. The invasion of Ogbadibo, Agatu and Apa local government areas in Benue South Senatorial District are however believed to be the most brutal. On February 29, for instance, the herdsmen invaded several Agatu villages and farm settlements in broad daylight, gunning down children, women, men and the elderly. At the time the gunshots subsided, over 500 villagers were reportedly massacred and over 7000 were displaced in 10 villages including Aila, Okokolo, Akwu, Adagbo, Odugbehon and Odejo, (vanguardr.ng and Premium Times,2016).

Model Formulation and Analysis

In this research, we limited our study to these two neighbouring local governments of the state namely; Ukum and Logo local governments. The reason being that the people are predominantly farmers; their nature of settlement (cluster) also gives room for herdsmen free grazing. A good number of streams in the study area hold water all year round.

The following are the model assumptions, parameters and variables:

i. Clashes/crises other than those between herdsmen and farmers are not considered;
ii. Clashes/crises between herdsmen and farmers is the major factor that retards agricultural/economic growth in Benue State
iii. No security for the people
iv. There is random mixing between the two local governments
v. Recruitment to the core groups is by birth/replacement
vi. The size of both local governments remain fixed since each Ukum and Logo person who relocates gets replaced immediately
vii. Security provision should be for both local governments(farmers) and herdsmen alike
viii. Security provision gives room for peaceful agricultural/economic activities
ix. Clashes/crises affect both farmers/herdsmen, all sexes of all ages without exception.

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The model parameters and variables:

$S_u(t)$ = Number of susceptible Ukum people at time t;
$A_u(t)$ = Number of affected Ukum people at time t;
β_{ul} = Rate at which clashes/crises from Ukum local government affects Logo local government per unit time;
μ_u = Natural mortality rate of Ukum people per unit time;
ρ_u = Relocation of Ukum people per unit time;
ψ_u = Turnover rate of the Ukum people ($= \mu_u + \rho_u$);
γ_u = Clashes/crises induced death rate to the Ukum people per unit time;
v_u = Fraction of all adult farmers from Ukum per unit time;
$U_u(t)$= Proportion of Ukum people that are protected at time t;
α_u = Rate at which Ukum people are protected per unit time;
N_u = $S_u + A_u$
$S_l(t)$ = Number of susceptible logo people at time t;
$A_l(t)$ = Number of affected Logo people at time t;
β_{lu} = Rate at which clashes/crises from Logo affects Ukum per unit time;
μ_l = Natural mortality rate of Logo people per unit time;
ρ_l = Relocation by Logo people per unit time;
ψ_l = Turnover rate of the Logo people ($= \mu_l + \rho_l$);
γ_l = Clashes/crises induced death rate to the Logo people per unit time;
v_l = Fraction of all adult farmers from Logo per unit time;
$U_l(t)$= Proportion of Logo people that are protected at time t;
α_l = Rate at which Logo people are protected per unit time;
N_l = $S_l + A_l$

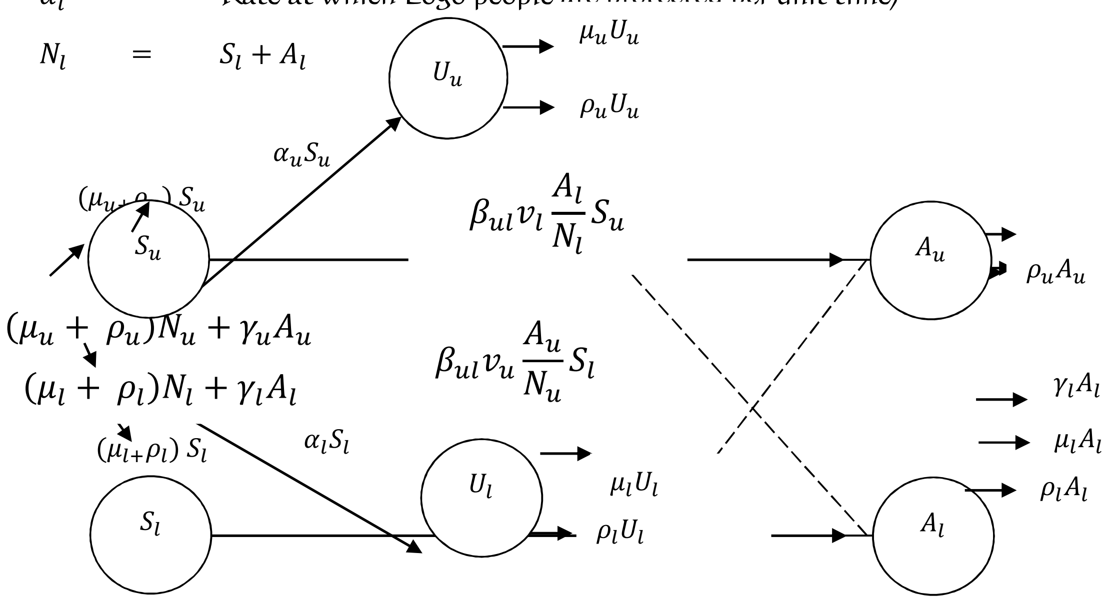

Figure 4: *A flow – diagram of the model*

The model equations are:

$$S_u' = (\mu_u + \rho_u)N_u + \gamma_u I_u - (\mu_u + \rho_u + \alpha_u)S_u - \beta_{lu} v_l \frac{A_l}{N_l} S_u \quad (1)$$

$$U_u' = \alpha_u S_u - (\mu_u + \rho_u)U_u, \quad (2)$$

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$A_u' = \beta_{lu} v_l \frac{A_l}{N_l} S_u - (\gamma_u + \mu_u + \rho_u) A_u,$ (3)

$N_u = S_u + U_u + A_u,$ (4)

$S_l' = (\mu_l + \rho_l) N_l + \gamma_l I_l - (\mu_l + \rho_l + \alpha_l) S_l - \beta_{ul} v_u \frac{A_u}{u} S_l$ (5)

$U'_l = \alpha_l S_l - (\mu_l + \rho_l) U_l,$ (6)

$A'_l = \beta_{ul} v_u \frac{I_u}{N_u} S_l - (\gamma_l + \mu_l + \rho_l) A_l$ (7)

$N_l = S_l + U_l + A_l$ (8)

Stability of the Crises Free Equilibrium (CFE) State of the Model Equations

In this section, the stability of the CFE state of the model is discussed as follows:

$f_1 = \alpha_u(1 - x - z) - \psi_u x,$ (9)

$f_2 = \alpha_l(1 - y - w) - \psi_l y,$ (10)

$f_3 = \beta_{lu} v_l w(1 - x - z) - (\gamma_u + \psi_u) z,$ (11)

$f_4 = \beta_{ul} v_u z(1 - y - w) - (\gamma_l + \psi_l) w,$ (12)

Differentiating (9) – (12) partially with respect to x, y, z and w respectively and applying the Jacobian matrix, the we have these beautiful results as follows

$(\alpha_u + \psi_u + \lambda) = 0 \Rightarrow \lambda_1 = -(\alpha_u + \psi_u)$

$(\alpha_l + \psi_l + \lambda) = 0 \Rightarrow \lambda_2 = -(\alpha_l + \psi_l)$

$\lambda_{3,4} = -A.$

Since, $\lambda_1, \lambda_2, \lambda_3$ and λ_4 are negative, we say that the CFE is locally and asymptotically stable (LAS).

The Numerical Method

We solved our system of equations 9, 10, 11 and 12 using Runge Kutta fourth order method and implemented in JAVA. The parameters $\alpha_u, \alpha_l, \gamma_u, \gamma_l, v_u, v_l, \beta_{lu}, \beta_{ul}, \mu_u, \mu_l, \rho_u, \rho_l$, as defined earlier are assigned specific hypothetical values in Table 1 below.

Table 1: Tables of Parameter Values for the Numerical Experiments

Fig. / Parameter	2	3	4	5	6	7	8
$x_{(0)}$	0	0	0.2	0.2	0.2	0.2	0.2
$y_{(0)}$	0	0	0.2	0.2	0.2	0.2	0.2
$z_{(0)}$	0	0.2	0.2	0.2	0.2	0.2	0.2
$w_{(0)}$	0	0.2	0.2	0.2	0.2	0.2	0.2
α_u	0	0	0.2	0.3	0.6	0.6	0.8
α_l	0	0	0.3	0.5	0.4	0.6	0.8
β_{ul}	0	0.35	0.35	0.35	0.35	0.35	0.35
β_{lu}	0	0.35	0.35	0.35	0.35	0.35	0.35
γ_u	0	0.1	0.01	0.01	0.01	0.01	0.01
γ_l	0	0.	0.02	0.02	0.02	0.02	0.02
v_u	0.03	0.03	0.03	0.03	0.03	0.03	0.03
v_l	0.05	0.05	0.05	0.05	0.05	0.05	0.05
μ_u	0.2	0.2	0.2	0.2	0.2	0.2	0.2
μ_l	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ρ_u	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ρ_l	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Hypothetical data

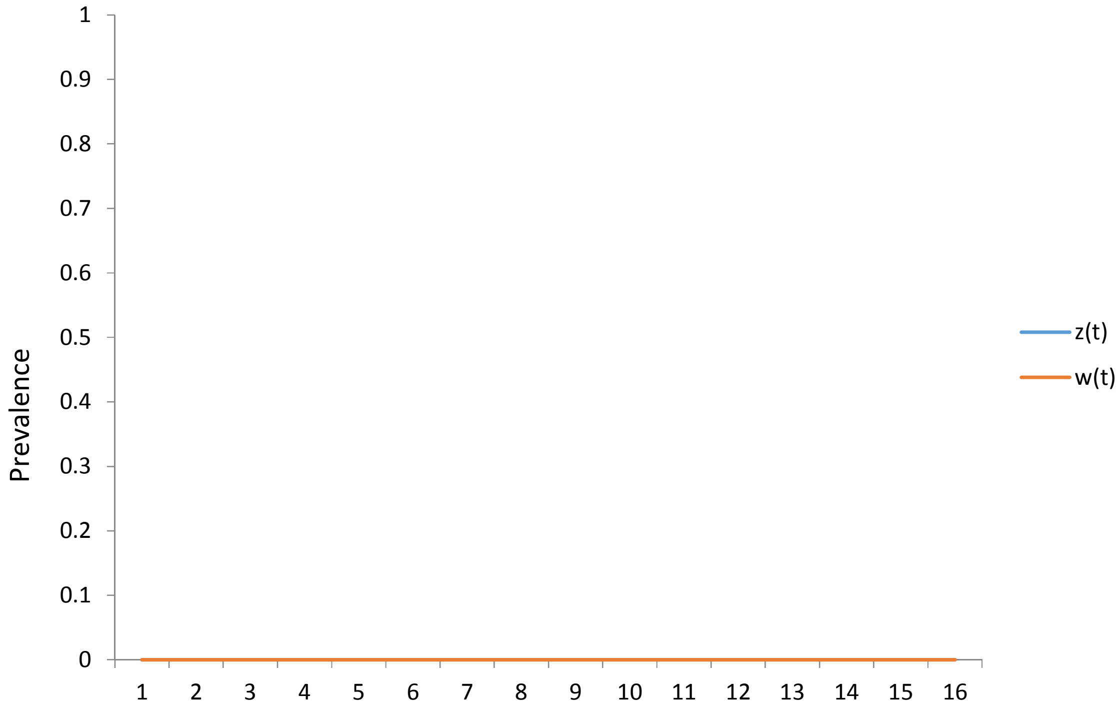

Fig 5: Graph of prevalence against time in the absence of herdsmen

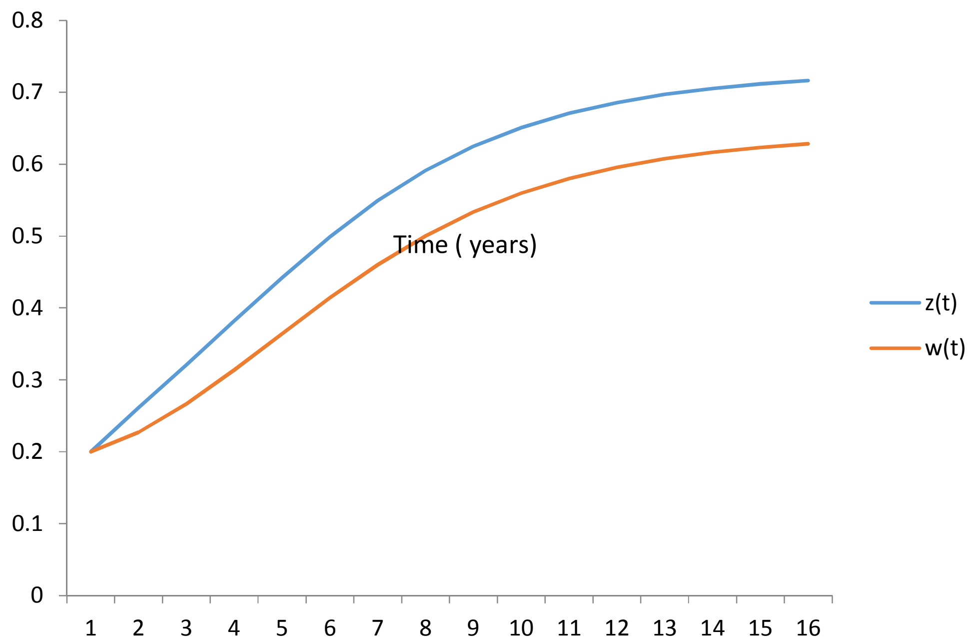

Fig 6: Graph of prevalence against time in the absence of security (numerical solutions are shown on column 3 of table 1)

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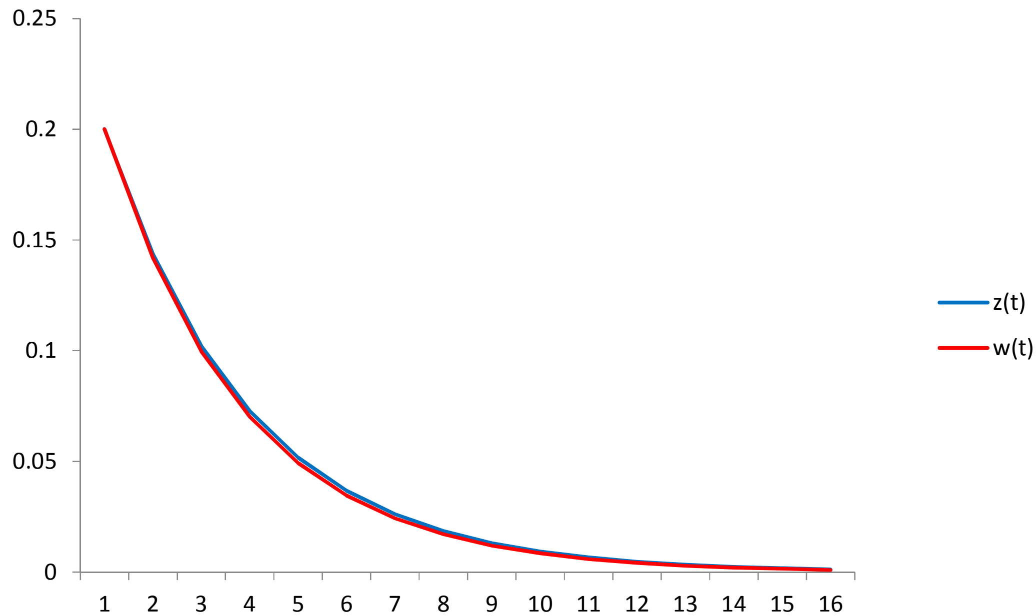

Fig 7: Graph of prevalence against time, in the presence of effective security, where $\alpha_u = 0.6 = \alpha_l$. (Numerical solutions are shown on column 7 of table 1)

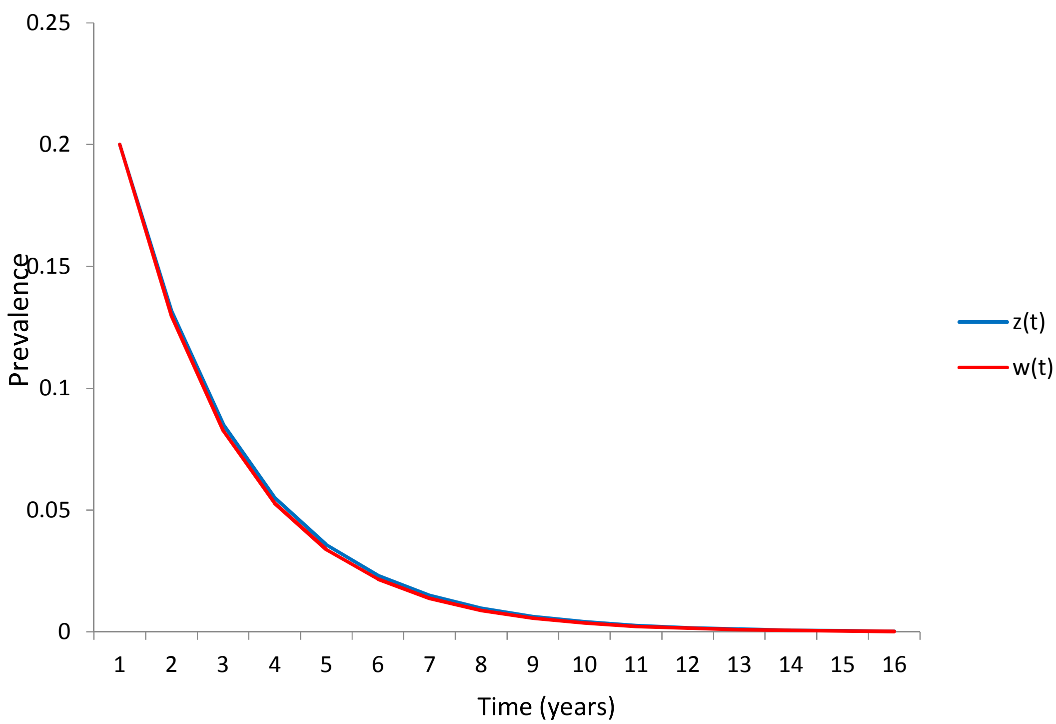

Fig 8: Graph of prevalence against time, in the presence of very effective security, where $\alpha_u = 0.8 = \alpha_l$. (Numerical solutions are shown on column 8 of table 1)

CONCLUSION

The model equations in proportions give prevalence of crises which has biological meaning. Runge-Kutta Fourth Order method was used in the numerical experiments. The existence and stability of the DFE state of the model was also established. It was found to be locally and asymptotically stable, whenever it exists. Numerical experiments, using hypothetical data (see Table1) also shows that effective security measures will completely control and eradicate clashes/crises from the area.

RECOMMENDATIONS

Based on the findings in the research, we wish to recommend that efforts be channelled towards very effective security in the study area. However, the proportion of those being secured should be sufficiently high to bring about control and eradication of the menace in infinite time. This can be achieved by acceptance of ranches through education of herdsmen, the use of effective law enforcement agencies and publicity through organization, community, and individual level. Other measures such as education of traditional rulers, mosques, churches could have even greater impact toward a successful programme.

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