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Model-Driven Engineering and Creative Arts Approach to Designing Climate Change Response System for Rural Africa: A Case Study of Adum-Aiona Community in Nigeria

Zastosowanie inżynierii sterowania modelami i sztuk pięknych w przygotowywaniu systemu reagowania na zmiany klimatyczne dla obszarów wiejskich w Afryce: przypadek wspólnoty Adum-Aiona w Nigerii

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Abstract

Experts at the just concluded climate summit in Paris (COP21) are unanimous in opinion that except urgent measures are taken by all humans, average global temperature rise would soon reach the deadly 2^{o}C mark. When this happens, socio-economic livelihoods, particularly in developing economies, would be dealt lethal blow in the wake of associated natural causes such as increased disease burden, soil nutrient destruction, desertification, food insecurity, among others. To avert imminent dangers, nations, including those from Africa, signed a legally binding universally accepted climate control protocol to propagate and regulate environmentally-friendly behaviours globally. The climate vulnerability of Africa as established by literature is concerning. Despite contributing relatively less than other continents to aggregate environmental injustice, the continent is projected to bear the most brunt of environmental degradation. This is on account of her inability to put systems and mechanisms in place to stem consequences of climate change. Hence, our resolve to use a combination of scientific and artistic models to design a response system for tackling climate challenges in Africa. Our model formulation encompasses computational model and creative arts model for drawing attention to environmentally friendly behaviours and climate adaptation and mitigation strategies. In this work, we focus on rural Africa to share experience of climate change impact on agriculture – mainstay of rural African economy. We examine the carbon footprints of a rural community in Nigeria – the Adum-Aiona community – as case study and for industrial experience. The authors will provide operational data to substantiate claims of existential threats posed by greenhouse gas (GHG) generation on livelihoods of rural dwellers. The study will also design and test a Climate Change Response System (CCRS) that will enable people to adapt and reduce climate change impact. To achieve the research objective, the researchers will review literature, gather requirements, model the proposed system using Unified Modelling Language (UML), and test CCRS statically. We expect that the implementation of the proposed system will enable people mitigate the effects of, and adapt to, climate change-induced socio-economic realities. This is besides the fact that the empirical data provided by the study will help clear doubts about the real or perceived threats of climate change. Finally, the industrial experience and case study we share from Africa using model-driven engineering approach will scale up the repository of knowledge of both climate change research and model-driven engineering community.

Key words: agriculture, climate change, visual and creative arts model, model-driven engineering, response system

Streszczenie
Eksperci biorący udział w szczycie klimatycznym w Paryżu (COP21) sugerują, że pomimo mimo podejmowanych działań zaradczych, średnia temperatura na naszej planecie podniesie się wkrótce o 2^0C. Gdy to nastąpi, społeczno-ekonomiczne podstawy bytu, szczególnie w krajach rozwijających się, zostaną naruszone w wyniku m.in. przewidywanego wzrostu zachorowań, zniszczenia gleby, pustynnienia i braku zabezpieczenia żywności. Aby zapobiec zbliżającemu się niebezpieczeństwu podpisano prawnie wiążący protokół klimatyczny, zaakceptowany także przez kraje afrykańskie. Jego celem jest uregulowanie i wsparcie dla zachowań prośrodowiskowych w skali globalnej. Opisywana w literaturze wrażliwość klimatu w Afryce wydaje się być szczególnie istotna. Chociaż w porównaniu do innych kontynentów jej udział w emisji zanieczyszczeń do atmosfery jest mniejszy, to właśnie ten kontynent ma dotknąć największy poziom degradacji środowiskowej. Wynika to m.in. z braku możliwości wdrażania kluczowych dla klimatu systemów i mechanizmów. Stąd wynika nasza determinacja w opracowaniu kombinacji naukowych i artystycznych modeli, służących jako narzędzia do formułowania systemu odpowiedzi na czekające Afrykę zmiany klimatyczne. Nasze podejście obejmuje modele obliczeniowy i odnoszący się do sztuk pięknych, które mają pomóc w zwróceniu uwagi społeczeństw na niezbędne zachowania prośrodowiskowe. W badaniach koncentrujemy się na obszarach wiejskich w Afryce, aby przedstawić wpływ zmian klimatycznych na rolnictwo, które stanowi podstawę afrykańskiego systemu ekonomicznego. Zbadaliśmy ślad węglowy obszarów wiejskich w Nigerii, we wspólnocie Adum-Aiona. Autorzy przedstawiają dane pokazujące realne zagrożenia dla ludzi, które niesie ze sobą emisja gazów cieplarnianych. Prezentowany jest także test odnoszący się do Systemu Odpowiedzi na Zmiany Klimatu, który pomoże mieszkańcom nie tylko w adaptacji do, ale także w zmniejszeniu konsekwencji zmian klimatycznych. Dyskusja zostanie wsparta przeglądem literaturowym, pomagającym lepiej określić wymagania, które powinien spełniać model, z wykorzystaniem UML. Należy się spodziewać, że wdrożenie proponowanego systemu przyniesie realne korzyści, także te noszące się do uwarunkowań społeczno-ekonomicznych. Rezultaty przeprowadzonych badań empirycznych precyzują zakres zagrożeń związanych ze zmianami klimatycznymi. W końcowej części odniesiemy się do doświadczeń związanych z przemysłem, także w kontekście Afryki. Zastosowanie inżynierii sterowania modelami wzbogaca zakres wiedzy odnoszący się zarówno w kontekście badań nad zmianami klimatycznymi, jak i możliwych zastosowań inżynierii.

Słowa kluczowe: rolnictwo, zmiany klimatyczne, wizualny i kreatywny model sztuki, inżynieria modelowa, system odpowiedzi

1. Introduction

In this work, we try to measure and simulated a climate-resilient rural Africa using the Adum-Aiona community in Benue State, Nigeria. To achieve this objective, we obtained climate data from the Nigeria Meteorological Agency (NIMET) in the form of its yearly seasonal rainfall predictions spanning 2011-2015. Africa is well known for its reliance on agriculture for socio-economic sustenance (Schroth et al., 2016; Webber et al., 2016). The fact, that this sector is not well developed results in heavy dependence on rain-fed model of agriculture such that weather changes greatly impact of its operations. Though developments in climate change impact other sectors such as transportation, construction, aviation, manufacturing, among others, the agrarian nature of Africa means that particular attention must be given to the agriculture sector (Perez et a., 2015; Li et al., 2015). Hence, the seasonal rainfall predictions of many national meteorological agencies across Africa are predominantly utilized in the agricultural industry (Seo, 2015).

Overtime, the failure of African governments to develop alternative to rain-fed agriculture such as irrigation farming means that the socio-economic lives of the people are impeded when factors such as weather change is not favourable to rain-fed agriculture (Jones et al. 2015). Incidences of drought, delayed rainfall, early cessation and dry spells take heavy toll on the sustenance of lives. The immediate consequences are food insufficiency and insecurity, hunger, poverty, unemployment and attendant social vices such as kidnapping, prostitution, and terrorism. Though there has been deliberate policies in the direction of encouraging irrigation farming, policy inconsistency and somersault over the years in various African countries has been the bane of the project (Kusangaya et al., 2014). As a result, frameworks like dams and river basins that known for potentials to channel surface water for irrigation farming are abandoned or left uncompleted.

On the other hand, activities of urban and rural dwellers continue to heighten greenhouse gasses (GHGs) emission. While in the urban African settlements, carbons emissions are pronounced through the burning of hydrocarbons (Steynor et al., 2016) in petroleum products such as kerosene, petrol and diesel for transportation, construction and manufacturing, rural communities engage in environmental injustice by felling trees during land preparation for farming, burning of firewood as source of cooking energy, and deliberate deforestation for purposes of transacting log business (Chidiebere et al., 2016). The aggregate effect is that the dearth of clean energy in Africa has increased the contribution of Africa to the rise in global temperature that is feared to be approaching the dangerous 2ºC threshold, except concrete steps are taken. Even more concerning is that though Africa contributes least to GHGs emission, ozone layer depletion and aggregate rise in global temperature among all the continents, studies have shown that it suffers most in terms of bearing climate change burden. This is because it has weak climate change response mechanism (Clarke et al., 2016).

In this study, we focus on filling this gap by designing a Climate Change Response System (CCRS). The policy thrust of CCRS is to sensitize people on ecologically friendly behaviours and climate adaptation and mitigation techniques leveraging creative art models such as dance, drama, and visual aid (graphics), communication. Though we take a general look at climate change impacts on both urban and rural Africa, our particular interest is on rural Africa as vast majority of agricultural activities take place there and majority of Africans dwell there. For case study and industrial experience, we use the Adum-Aiona community in Nigeria, precisely in Benue State. The community is an agricultural hub and its host state, Benue, is known as the food basket of the nation. CCRS captures initiatives that promote environmentally friendly behaviours as well as spell out adaptation and mitigation techniques for surviving climate-challenged environment. Using model-driven engineering approach, we design CCRS using unified modelling language (UML) and test the proposed system statically (Sirohi, Parashar, 2013; Gorton, 2011). Besides closing a contextual gap, the case study and industrial experience shared add to bodies of knowledge of both the model-driven research community and climate change research community. The evidence provided by way of literature review of various case studies, and operational data from the Nigerian Meteorological Agency on Seasonal Rainfall Predictions also help in substantiating the existential threats posed by climate change to the human race.

The remaining segments of the article is partitioned thus: In Section 2, there is review of literature; adopted methodology for the research is outlined in Section 3; Section 4 discusses results; and in Section 5, the work is concluded.

2. Review of Literature

2.1. Climate Change and El Niño in Africa

A change in weather patterns measured in statistical distribution, which lasts for a length of time, say decades to millions of years, is termed climate change. Put in another fashion, it refers to average weather conditions alteration. Climate change can also be seen as more or fewer extreme weather events which implies time change in weather around longer-term average conditions. Factors such as changes in solar radiation received by Earth, biotic processes, volcanic eruptions and plate tectonics are responsible for climate change. Also, some human activities are direct or indirect causes of contemporary climate change, called global warming (Kahsay, Hansen, 2016).

Organizations, like Climate Action Network Europe and Germanwatch, are known to be the publishers of the annual publication called *The Climate Change Performance Index* (CCPI). It is a barometer for evaluating 58 countries with regards to climate protection performance and these countries are responsible for more than 90% of world energy-associated CO_2 emissions. In 2013, CCPI publication covered CO_2 generated from sources such as fossil fuels, with the exception of emissions from the shipping sector. Subsequent CCPI publications took into cognisance emissions from waste, deforestation and agriculture. The evaluation is made up of the following compositions: emission trend is 50 %, emission level constitutes 30% while the remainder of 20% comes from assessment of over 200 experts on national and international climate policy. Recent results (as published in December 2014) indicate that more efforts are required to avert dangerous climate change. Hence, no country was ranked one to three in the 2015 results. However, Denmark was acknowledged for her efforts even as she topped the list (Calzadilla et al., 2014).

El Niño Southern Oscillation (ENSO) has a warm phase known as El Niño. In the region of the International Date Line and 120°W (off the Pacific coast of South America inclusive), there is a band of warm ocean water that develops in the central and east-central equatorial Pacific which is associated with El Niño. ENSO can also be seen as the cycle of warm and cold temperatures which is measured by sea surface temperature (SST) of the tropical central and eastern Pacific Ocean. Typically accompanying El Niño is low air pressure in the eastern Pacific and high air pressure in the western Pacific. However, the cool phase of ENSO is known as La Niñais and normally characterised by SST. In the eastern Pacific, it is below average but the air pressures are high in the eastern Pacific and recording low in the western Pacific. Outcomes of the ENSO cycle – both El Niño and La Niña are directed by global changes in temperatures and rainfall (Young et al., 2016).

Study is ongoing on mechanisms that cause the oscillation.
Developing countries such as African countries depend largely on agriculture and fishing for survival. The most affected countries are those bordering the Pacific Ocean (Wündsch et al., 2016). In recent times, climate change tends towards more extreme El Niños, as shown by measurements and simulations. In Africa, the impact of the phenomenon differ from one region to another – in some parts such as Kenya, Tanzania, and South Africa, long rains and wetter-than-normal conditions are experienced between March and May. In others, drier conditions than normal exist such as in Zambia, Zimbabwe, Mozambique, and Botswana from December to February. Direct impacts of El Niño responsible for drier conditions are experienced in some parts of Northern Australia and Southeast Asia resulting in worsening haze, intense bush fires, and significant reduction in quality of air. Conditions that are drier than normal characterise certain parts of the globe at some time of the year (Calatayud et al., 2016).

2.2. Sustainability and Social Consequences of Climate Change in Africa

Human survival is a function of the environment. All aspects of human survival need structures that operate in a given environment, social services (health, education and agriculture) inclusive. The decimation of the environment means livelihoods are directly or indirectly impacted upon negatively. In the Horn of Africa (Ethiopia, Eritrea and Somalia) for example, there is presently humanitarian crisis partly due to drought and food shortage as a result of unfavourable and unpredictable climatic conditions (Clarke et al. 2016). The consequent desert encroachment has not only left in its trail hunger but also diseases (Grace et al., (2015).
The impact of desert encroachment is also taking its toll on Northern Nigeria, where herdsmen are known to be leaving the area massively for Southern Nigeria in a bid to sustain their animals as a critical component of their pastoral (nomadic) life. The adverse effect of climate change has not only shrunk water sources for human and animal consumption (Kusangaya et al., 2014) but equally impacted on irrigation farming (Kahsay, Hansen, 2016; Calzadilla, 2014). On the other hand, the massive migration has resulted in ethno-religious crisis and even ethnic cleansing (Clionadh et al., 2015) in some extreme cases due to frequent clashes between farmers and herdsmen over grazing lands. Consequently, the Nigerian government is currently putting agricultural policies in place in the direction of creating grazing reserves to check the incessant loss of human lives and cater for the animals in the most efficient and effective manner for optimal productivity.
In the coastal cities of Africa, ocean surge has been known to destroy corporate buildings hosting multinational companies and destroying road infrastructure thereby hindering coastal economies (Wündsch et al., 2016). Also, buildings whose initial plans did not envisage or factor in harsh elements of the unfolding climatic conditions, are suffering structural defects (Chinowsky et al., 2014). This has serious implications for commerce and socio-economic development. In Eastern Nigeria, gully erosion has decapitated valuable lands that should have been used for commerce, industries and agriculture. Huge budgetary allocations that otherwise should have been used for enhancing the wellbeing of the citizenry through the provision of social services are being channelled to ecological management (Klausbruckner et al., 2016).
As a mitigation measure, there has been increased emphasis on the use of renewable energy in Africa (Fant et al., 2016) but lack of infrastructure has been the bane of such sustainable development initiative.

2.3. The Nigerian Metrological Agency (NIMET)

The Nigerian Meteorological Agency (NIMET) is a government parastatal that undertakes the production and issuance of seasonal rainfall prediction (SRP) for Nigeria in line with the agency's responsibility of advising government on all matters bothering on weather and climate. The SRP has gained popularity over the years and it is now largely patronized by stakeholders in climate-sensitive sectors of the economy (Bellprat et al., 2015). The scientific information it garners serves as input in planning and decision making.
The predictions are hinged on the intense tele-link between Sea Surface Temperature anomalies, El-Nino/Southern Oscillations (ENSO), and rain-bearing systems in Nigeria. In some years, SRP is predicted under the La-Nina phase and later revised to the neutral phase of the ENSO phenomenon. Despite the alternating affairs between La-Nina and El-Nino, Nigeria is characterised by ENSO-neutral conditions as the most dominating climate scenario. In most parts of the country, the ENSO-neutral phase is responsible for normal weather and climate conditions. In fulfilment of its statutory function of providing credible meteorological information, early warnings, forecasts, and advisory to guarantee informed decisions in all weather-sensitive and climate-conscious sectors of the economy, NIMET predicts annually and presents same to stakeholders for contributions on the socio-economic impacts prior to making predictions public. The release of the SRP is done early in the year so that policy makers will have sufficient time to factor in the critical information and advisories contained in it into the process of decision-making. This way, risks associated with harsh weather and climate are mitigated by the agency, and safety of lives and property guaranteed (Zinyengere et al., 2013). This initiative contributes significantly to Nigeria's sustainable socio-economic development.

NIMET relies on the following input data for the production of the annual SRP:

- Historical daily rainfall, maximum and minimum temperatures.
- Daily solar radiation data.
- Phenological and soil information data.
- El Nino/Southern Oscillation (ENSO) phase as defined by the Sea Surface Temperature irregularities.
- Rain-related synoptic systems for Nigeria.

2.4. A Model-driven Engineering Approach

The term Model-driven Engineering (MDE) is a methodology for software development with focus on exploiting and creating models of domain (Martínez-García et al., 2015; Wautelet, Kolp, 2016). The domain models (task model, quality model, data model, among others) are conceptual models of all aspects of a problem. For example, a climate change response application domain would emphasize representations of environmentally friendly behaviours, climate data local to a region, adaptation and mitigation techniques using standard modelling tools. Thus, MDE concentrates on representing knowledge and tasks in abstract format for guiding a domain application. Computing or algorithmic concepts are not its focus (Riesenfeld et al., 2015; Calegari et al., 2016).

MDE has potential for increasing productivity in that it maximizes systems compatibility by reusing models that are standardized (Davies et al., 2014). Also, by relying on models of the application domain with recurring design patterns, it simplifies the process of design (Gurunule, Nashipudimath 2015). Finally, individuals and teams jointly working on systems can have better communication owing to the use in the application domain of standardized practices and terminology (Barbier et al., 2015).

An MDE modelling paradigm is effective if two conditions are fulfilled – the models make sense to a user that is conversant with the domain, and secondly, they are capable of serving as the basis for implementing systems (da Silva, 2015). Collaborative efforts are involved in models development via intense communication between designers, product managers, users, and developers of the domain application. The completion of the models enhances the development of software and systems (Davies et al., 2015).

Some popular MDE projects includes (Ciccozzi et al., 2013; Rutle et al., 2015): Computer-Aided Software Engineering (CASE), Unified Modelling Language (UML), Object Management Group (OMG), Eclipse ecosystem of programming and modelling tools (Eclipse Modelling Framework), model-driven architecture (MDA), among others. Studies have shown that MDE technologies are promising in addressing the inefficiency of third-generation languages with respect to alleviating platform complexity and expressing domain concepts maximally (Hutchinson et al., 2014; Lütjen et al., 2014).

It is worth reiterating that modern systems design demands efficiency in handling their dynamic complexity (Cervera et al., 2015). In order to reduce the complexity, there is need for overhauling the entire system development process and take a second look at the age-long division among development phases. Since MDE shifts the focus from code to models, it is a veritable way of mitigating development complexity (Wehrmeister et al., 2014). The effective utilization of MDE reduces costs and risks in a number of ways: facilitating efficient modelling and analysis of functional and non-functional requirements; defining and implementing loosely coupled components into assemblies as a way of improving reusability; and in the course of development, making provision for automation where necessary (García-Magariño, 2016).

2.5. Creative Arts Model for Climate Change Sensitization and Mobilization

Creative Arts is the study of the power to form or to build out of nothing or something by force of imagination and talents. It is sub divided into two, namely Visual and Non-visual art (Babatunde, 2007). Visual arts are those aspect of art whose products are visible while Non-visual arts are those whose product cannot be seen with the naked eyes. Non-visual art are mainly for entertainment and recreation. While visual arts are for either beautification or applied.

For the sake of this study, the creative art model for climate sensitization and mobilisation includes one aspect of Non-visual arts and one aspect of Visual arts that has been employed for their effectiveness on how they have been used in different scenarios to effectively tackle societal issues. The two aspects are performing art (Non-visual) and Graphic art (Visual).

Performing (Non-visual) Art includes dance and drama which is performed to inform, sensitise or entertain an audience. Carnival performance is also an aspect of performing art that has been used to sensitise the society in divers ways. According to Akande (Akande, 2016), top government officials unveiled the theme of the 12th edition of the carnival which took place in 2015 as *Climate Change*. They remarked that it was necessary to explore the subject further, as more and more countries in the world continue to show concern for the environment. Thereafter, they led other government officials, the locals and revellers in a five million tree-planting campaign which was also in tune with the theme of the 2015 event (Fig. 1). According to Akande, the governor maintained that his administration will plant five million trees to support afforestation and climate change. In company of acrobatic dancers and music blasting trucks, richly costumed girls in green led each group as revellers took over the carnival routes cheering participants. Other side attractions included celebrities, masquerades, exquisite floats, and notable disc jockeys. Notably, the designs of the floats

Figure 1. Richly costumed girls in green dancing and leading the group at 2015 Calabar carnival in Nigeria tagged *Climate Change*, source: *The News Mongers*

Figure 2. Dignitaries dressed in foliages at 2015 Calabar carnival in Nigeria tagged *Climate Change*, source: *Gist Nigeria Blog*

were carefully crafted to depict *Climate Change* (Fig. 2).

True to its name, Graphic (Visual) Art has to do with vision or sight i.e. art works that can be seen. Visual art is also sub divided into the fine and applied arts. Graphics falls under applied art because it aids understanding in reading through visual images and text. Graphic design is a commercial art which service our visual communication system in producing designs like posters, signage, Book covers, labels, packages and so on. Maa Illustrations (2015) opine that to capture public attention, visual images play a significant role. The essence of illustrations in advertising is to pass a strong message to the audience. It presents a strong appeal to the target audience to focus on the advertisement.

Overtime, graphics design as part of the creative art model for climate sensitization and mobilisation has yielded effective way of communicating to members of a society through visual presentations combined with text, it simplifies ideas and makes it understandable to an averagely educated community. Graphics has been used to pass on simple but clear messages of prohibitions such as *Do not cut trees* (Fig. 3) and *No felling and burning trees* (Fig. 4).

Creative arts model for Climate Change Sensitization and Mobilization is a model that is an effective way of disseminating, sensitizing and informing the

Figure 3. Graphic art *Do Not Cut Trees Sign*, source: *Free digital photos*

Figure 4. Graphic art *No tree felling, no fires*, source: *Dreams time*

society of the need to be cautious. It catches the people's attention in terms of performing arts. The society is very much in tune with dance, drama and songs and would quickly align with whatever information that is coming out of these and that is why performing art is strategic to information broadcast to the people. Graphics art as a second tool under this model presents dual advantage for this course. It simplifies information for both learned and an average learned society with the utilisation of images and text.

The creative art model as presented in this study will be appropriate to disseminating information to the populace of Adum-Aiona Community regarding climate change, especially if this model is presented in the indigenous language of the people.

2.6. Related Work

In the literature, previous works that have bearing with model-driven engineering and climate change are as follows: (Lukman et al., 2013; Brunelière et al., 2014; Bubeck et al., 2014; Panesar-Walawege et al. , 2013; Cuadrado et al., 2014; Chabridon et al., 2013; Brambilla, Fraternali, 2014), discussions centred on MDE. The application of model-driven engineering in various fields of endeavours such as software development, industrial robotics, safety standards, software enterprises, web user interactions, among others were discussed. The authors were unanimous in their submissions that MDE not only enhances stakeholders' understanding of proposed system, it elicits support from stakeholders and engineers their commitment to the implementation of the system. This way, MDE contributes immensely to problem solving. As exhaustive as the discussions were, the authors did not mention the application of MDE for developing climate change response system. This is our key motivation in this work.

Ofoegbu et al. (2016) carried out an assessment of the adaptive capacity of forest-based rural communities and their coping strategies against climate variability using a South African Vhembe district as case study. The study has striking resemblance with ours in that it highlights the many coping initiatives used by forest-based rural settlers in Vhembe District of South Africa in order to acclimatize with climate variability so as to cushion attendant difficulties. The study observed that the nature of climate variability and extreme weather were chief determinants of survival strategies adopted such as rainwater harvesting, for coping with erratic rainfall, tree planting around houses and on farm land to counter the effects of extreme temperature. In addition, household and community demographic characteristics such as education and skills levels impacted on their response capabilities. Other critical factors for adapting and mitigating climate challenges include availability of forest products, institutional services and social infrastructure such as markets and water. The authors concluded that rural communities' resilience to climate change and variability challenges could be enhanced strengthening household's capacity and community infrastructural development. As closely related as the study is, it focused on the local exigencies of a South African communities whereas our study focus on Nigerian communities, using one as case study.

Steynor et al. (2016) shared experiences from urban Africa on co-exploratory climate risk workshops. The treatment opined that co-production has been acknowledged as cardinal to proper use and uptake of climate information into decision-making. Nonetheless, the authors observed, the success of co-production is a function of the natural understanding of the domain in which it is implemented. The article x-rayed the context for a place-based co-exploratory analysis of parameters such as climate risks, the elements and steps incorporated in the approach, among others. The co-exploration approach complements the objectives of the Global Framework for Climate Services just as it underscores heightened integration of climate information into urban adaptation planning in Africa. Despite stressing the benefit of climate time and sufficient information in planning, decision making and project execution in urban Africa, less attention was given to the climate change challenges of rural Africa which forms about 70% of the continent.

On his part, Seo (2014) relied on Agro-Ecological Zone (AEZ) techniques to examine how climate change impacts on decisions bothering on micro farming in sub-Saharan Africa (SSA). Relying on observed farming decisions in SSA, the work focused on understanding agriculture and assessing climate change impact on it with the aid of AEZ methods. Using the AEZ categorization of African continent and the idea of the Length of Growing Period (LGP), the author explained AEZ method. The World Bank household surveys which covered about 8000 farms spread across 9 sub-Saharan countries provided statistics on Farmers' decisions. Despite providing informed direction on effect of climate change on agriculture, the article did not suggest a climate change response system, the main motivation of our study.

In summary, none of the studies reviewed dwelt on closing the gap of designing a climate change response system (CCRS) using model-driven engineering for rural Africa. This is the gap we address in the following sections of the article.

3. Methodology

Our study focused on the carbon and ecological footprints of the Adum-Aiona community, estimating the impact of human activities on greenhouse gases (GHGs) emission into the atmosphere and destruction of soil texture that paves way for soil erosion and allied ecological problems. Our study revealed that both carbon and ecological footprints impact adversely on the livelihoods of the community whose mainstay is agriculture. We tabulate our findings as shown in Table 1.

Against the backdrop of established negative impacts of climate change on socio-cultural and socio-economic lives of Africans in general and rural Africans in particular (Raleigh et al., 2015), a response system that outlines measures for adapting to the new climate-engineering environment and that will also mitigate the adverse resultant effects will be handy in alleviating the sufferings of the people. The response system should also be proactive by adopting measures that promote ecologically-friendly disposition so that people are conscious that their environment-related behaviours have consequence for their continues survival (Grace et al., 2015).

There is no gainsaying the fact that vast majority of Africans rely on agriculture for survival. Hence, weather uncertainties as dictated by climate change has direct implications for livelihoods as Africa relies largely on rain-fed agriculture (Lim et al., 2016). The case study used is the Adum-Aiona community in Benue State of Nigeria. Like many rural African communities, it is an agrarian settlement in the Middle Belt (North Central) region in Nigeria. The so-

Table 1. Carbon and ecological footprints of Adum-Aiona Community

SN	Activity	Impact on Global Warming (El Nino) and Ecology	Effects
1.	Cooking using firewood	Emission of greenhouse gases (GHGs)	Excessive heat waves that cause human discomfort and encourage spread of diseases such as meningitis.
2.	Pressing iron (charcoal iron)	Emission of CO_2 into atmosphere	Heated atmosphere resulting in depletion of ozone layer and attendant consequences.
3.	Tree felling	Destruction of trees that utilizes CO_2 for photosynthesis, in the process reducing CO_2 in the atmosphere. Also, tree roots hold soil tight for water absorption, preventing flooding. Trees absolve GHGs that contribute to GW and CC.	Erosion and degradation of soil nutrients that reduce agricultural productivity leading to food insufficiency and insecurity, unemployment and social tensions.
4.	Bush burning	Release of GHGs into atmosphere	Destruction of soil texture, flora and fauna, impacting on agricultural productivity, hunger and poverty.
5.	Body warming using firewood	Emission of CO_2 into atmosphere	Heated atmosphere resulting in ozone layer depletion and related consequences
6.	Food preservation through smoking	Release of CO_2 into atmosphere	Heated atmosphere resulting in ozone layer depletion and related consequences.
7.	Harmful farming practices	Destroyed soil texture, hence decreased capacity to absolve water leading to flooding	Flooding destroys means of livelihoods and further impoverish the people.
8.	Indiscriminate burning and dumping of waste products	Heated and polluted atmosphere as well as destruction of soil texture	Excessive heat waves and depletion of soil structure. These encourage heat-borne diseases, soil erosion and soil nutrients depletion.

cio-economic lives of the people revolve around rain-fed agriculture with crop planting done during raining season while the dry season is used for harvesting and processing. The raining season typically spans the months of March to October while the dry season covers November to February. Typical crops planted include food crops such as yam, cassava, maize, sorghum, millet, and beniseed. Tree crops found in the community include palm trees and cashew trees while fruits include mango and orange. The seasonal rainfall predictions for year 2016 by NIMET suggests the country will experience late onset of rains and early cessation with dry spells in-between. As indicated in the use case diagram showing the CCRS above, for purposes of acclimatization and mitigation of the consequences of this climate change fall-out, farmers in Adum-Aiona have to be sensitized and educated on climate resilient agriculture via the instrumentality of both formal and informal institutions. Formally, extension services will be used to disseminate information on climate-compliant agricultural practices and inputs as well as rainfall prediction information by NIMET. Informal institutions like worship places (particularly churches since the people are predominantly Christians), town hall meetings, family meetings, and age-grade meetings are further avenues that could be explored for the same purpose which are quiet potent for the domestication and ownership of the climate change response system. The use of drama, dance drama, dance and songs performed in the local Idoma language during informal gatherings will go a long way in driving home the message of potential challenges posed by climate change and the need to take proactive measures. In addition, visual aid such as posters and hand bills illustrated and written in the local language and posted at strategic positions will also lend a voice to the campaign.

In the meantime, our study has revealed that farming practices of the Adum-Aiona farmers could exacerbate climate change impacts. Some of the environmentally unfriendly behaviours include indiscriminate tree felling during land preparation, burning of fossil fuel through the use of firewood for cooking, and indiscriminate cutting of trees for logs (Klausbruckner et al., 2016). While the community justifies deforestation by citing agricultural and commercial expediencies, the use of firewood for cooking has been substantiated by the lack of alternative source of clean energy. Though the community is located in Nigeria, an oil producing country, the inability of the country to curtail gas flaring and use same for supplying clean gas energy means the people continue to burn hydrocarbon fossil fuels – firewood, kerosene, petrol and diesel for survival. Even though the Adum-Aiona community's vegetation is relatively green and dense, these human activities certainly escalate emission of greenhouse gases

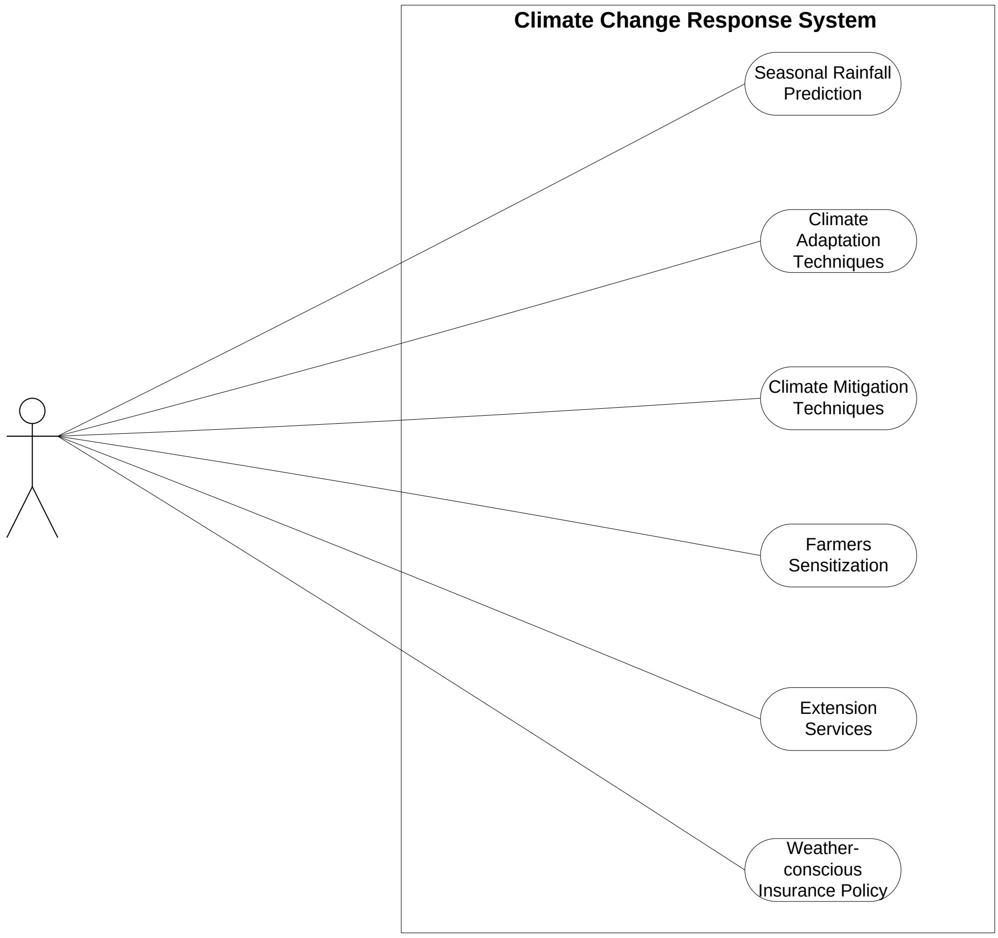

Figure 1. Use Case Diagram for the Climate Change Response System (CCRS)

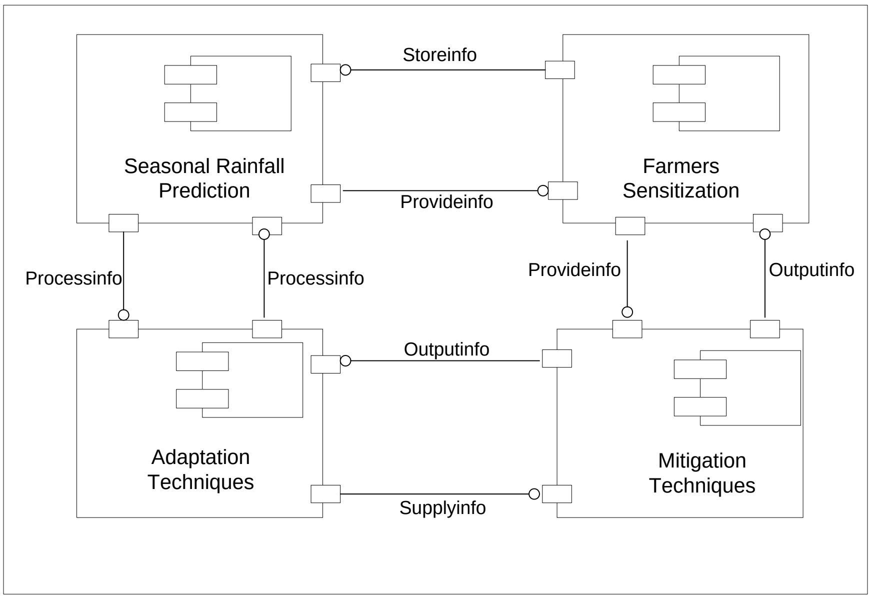

Figure 2. CCRS component diagram

(GHGs), contribute to rise in global temperature tending towards the 2°C mark, and deplete the ozone layer (Chinowsky et al., 2014). Hence, CCRS contains a component that not only sensitizes and educates the rural dwellers on climate adaptation techniques but also enlightens them on ways of mitigating carbon emissions (van Wesenbeeck et al., 2016).

3.1. Requirements Analysis and Modelling

Our proposed Climate Change Response System (CCRS) contains mechanisms (actions) that promote environmentally friendly disposition and climate-resilient agriculture as depicted in Fig. 1 using Unified Modelling Language (UML). The requirements as captured in the diagram include uses cases (actions) such as *Seasonal Rainfall Prediction, Climate Adaptation Techniques, Climate Mitigation Techniques, Farmers Sensitization, Extension Services* and *Weather-conscious Insurance Policy.*

The *Seasonal Rainfall Prediction* will empower farmers and other climate change stakeholders with information on rainfall patterns as provided by the national meteorological agencies such as the Nigerian Meteorological Agency (NIMET). This will enhance planning, decision making and execution of socio-economic projects in agriculture, construction, transportation, water resource management, telecommunication, among others (Moyo, Nangombe 2015).

The *Climate Adaptation Techniques* component will highlight to farmers and other stakeholders updated techniques for adapting to the climate-induced environment. They include, but not limited to, construction of dams and river basins for harnessing surface and underground waters for irrigation, domestic and industrial purposes. Others are digging of wells, planting crops with short life span, sowing disease resistant crops, growing climate-resistant crops, and provision of social infrastructure and amenities (Fant et al., 2016).

The *Climate Mitigation Techniques* sub-system will provide information on measures to reduce emission of greenhouse gases (GHGs). This includes afforestation, discouraging bush burning, recycling of waste products, and use of clean energy instead of hydrocarbon energy, among others.

The *Farmers Sensitization* use case outlines the use of Creative Art models such as dance, drama, posters and hand bills, dance drama, among others through informal institutions such as worship places, family meetings, festivities, age group meetings, etc. for sensitizing and educating farmers on climate change challenges and ways to adapt and mitigate them. This advocacy initiatives are aimed at helping rural dwellers internalise and institutionalize ecologically friendly behaviours, adapt to climate-induced environments and atmosphere, and mitigate the challenges posed by weather and climate vagaries.

The *Extension Services* is a system component that highlights the various services that government Extension Services render to farmers viz-a-viz ecologically friendly behaviours, climate resilient agriculture and climate change mitigation initiatives. Besides traditional extension services such as information on new farming techniques, new agricultural inputs, irrigation, disease resistant crops, drought-resistant crops, there is increased advocacy by climate experts that seasonal rainfall predictions should be an integral part of the extension service package on account of the overbearing impact of climate on agriculture (Kahsay, Hansen, 2016; Calzadilla et al., 2014).

The *Weather-conscious Insurance Policy* is a safety net measure for losses that may be incurred by farmers as a result of carbon and ecological footprints (climate change-induced challenges) such as drought, flood, late onset and early cessation of rains, dry spells, among others (Perez et al., 2015; Kahsay, Hansen, 2016; Bellprat et al., 2015; Zinyengere et al., 2013).

3.2. System Design

Though there are many functionalities offered by CCRS, they can be broadly categorised into four cardinal components, namely *Seasonal Rainfall Prediction*, *Farmers Sensitization*, *Adaptation Techniques* and *Mitigation Techniques* as shown in the Component Diagram in Fig. 2.

The class diagram in Fig.3 captures interactions among these sub-systems. Both component and class diagrams graphically indicate interactions among the four core components of CCRS – *Seasonal Rainfall Prediction*, *Farmers Sensitization*, *Adaptation Techniques* and *Mitigation Techniques* with varying details. While the component diagram depicts these sub-systems as loosely coupled components capable of independence to some extent, the class diagram gives details of attributes, methods and cardinality. In summary, CCRS relies on *Seasonal Rainfall Prediction (SRP)* for climate data that are disseminated to stakeholders including the rural farmers for purposes of planning, decision making, and execution of socio-economic projects that enhance livelihoods. The *SRP* data serve as input into Farmers *Sensitization* that encompasses the use of advocacy and climate change education through formal and informal institutions using creative arts models (dancing, graphics, posters, handbills, etc.) to drive climate change messages. The interaction with *Adaptation Techniques* sub-system ensures that farmers are abreast of measures such as climate-resistant crops, use of dams and river basins for irrigation farming as alternative to rain-fed agriculture, among other adaptation measures. Finally, the system interaction places the onus on the *Mitigation Techniques* component to avail farmers information on measures to reduce impact of climate change such as afforestation, proper waste disposal initiatives, use of clean energy as alternative to firewood and other sources of fossil fuels, among others.

The database platform of the CCRS is hinged on Seasonal Rainfall Prediction (SRP) data whose entities and relationships are shown in the entity relationship diagram (ERD).

The narrative of the ERD is to the effect that every state in Nigeria has an SRP made available by NIMET. The attributes of a state include cities, *longitude* and *latitude* while the seasonal rainfall predi-

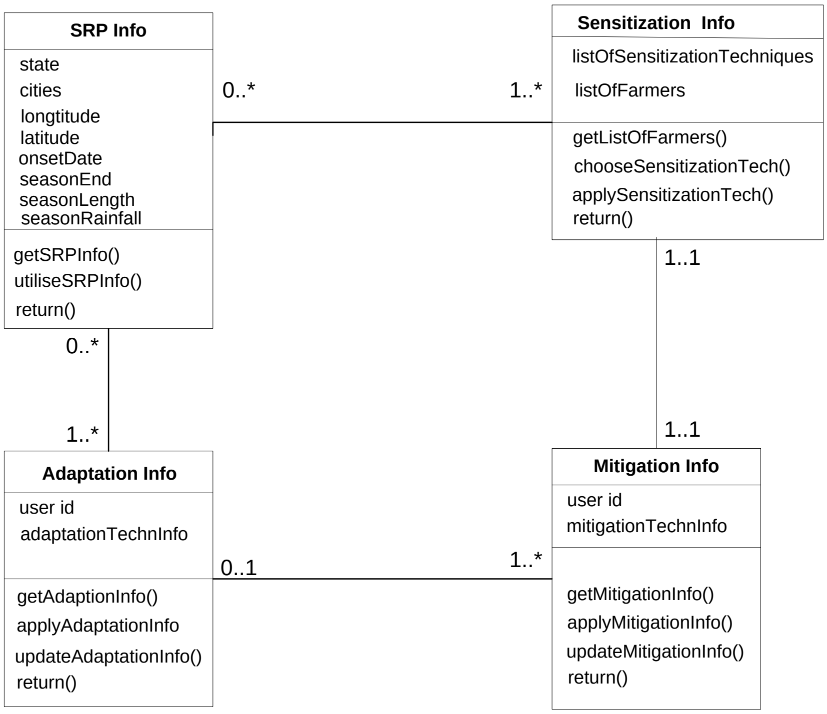

Figure 3. Class Diagram for the Climate Change Response System (CCRS)

ction is characterised by attributes such as *onset date*, *season end*, *season length* and *season rainfall*. The ERD further specifies that every state must belong to one of the agro-ecological zones in Nigeria (*Sahel Savannah, Swamp Forest, Guinea Savannah, Tropical Rain Forest, Sudan Savannah*).

3.3. System Verification and Validation

The climate change response system was validated and verified for requirements-compliance and process-correctness of the climate change adaptation and mitigation architecture by checking the different model representations – design documents, requirements documents, and pseudocode. The focus was to ensure that user requirements were well catered for in each model representation. Also, to be sure that the climate change adaptation and mitigation techniques meet ecologically-friendly and climate-resiliency needs rural dwellers in Adum-Aiona community and other similar rural communities in Africa.

The essence of the validation phase is to scale up confidence that the climate change response architecture is fit for purpose (Gorton, 2011). Our technique for validating this architecture is purely static verification and validation (Sirohi, Parashar, 2013) which uses test scenarios for manual testing of the architecture. The essence is to ascertain if flaws exist in the CCRS design so as to correct them prior to implementation.

We verified and validated the CCRS architecture by checking the various model abstractions – design documents, requirements documents, and pseudocode to ascertain that sufficient mechanisms that drive environmentally friendly behaviours and promote climate-resiliency have been built into the proposed CCRS. The requirements traceability matrix is shown in Table 2.

4. Results and Discussion

4.1. Discussion of Outcomes

NIMET has provided the 2015 SRP (prediction) in fulfilment of its statutory obligation to make available credible meteorological information, advisory, forecasts, and early warnings to guide informed decisions in sectors that are climate and weather-sensitive such as agriculture, construction, etc. Prior to public presentation, the prediction is scrutinized by major stakeholders with a view to making inputs.

Our study focused on Adum-Aiona Community in Orokam, Benue State. Hence, we extracted data from NIMET on the 2015 seasonal rainfall predictions for Benue State located in the middle-belt region of Nigeria. After a careful study of the data, we observed that the database needed to be cleaned up (as there were clear instances of duplicated data) for expected research outcome to be achieve. Hence, we normalize the data by eliminating duplicates, with a new database as shown in Table 3.

The statistics above show the impact of El Nino and climate change on seasonal rainfall pattern in Benue State, North-Central (Middle-Belt) Nigeria. However, for comparative analysis, we further provide seasonal rainfall patterns of the Adum-Aiona community and its surrounding environments in Benue State using SRPs for 2011-2014 as shown in Table 4.

Table 2. Requirements traceability matrix

Requirement ID	Climate Requirements	CCRS Mechanism	Verification and Validation
CCRS01	Stakeholders to adequately be informed about weather and climate vagaries for planning, decision making and execution of socio-economic initiatives	The Seasonal Rainfall Prediction sub-system	Catered for
CCRS02	Advocacy campaign and education of farmers for ecologically-friendly behaviour	The Sensitization Information sub-system	Catered for
CCRS03	Adaptation for climate-induced environment for survival	The Adaptation Techniques sub-system	Catered for
CCRS04	Minimizing the impact of global warming and El Nino on means of human livelihoods	The Mitigation Techniques sub-system	Catered for

Table 3. Normalized 2015 Seasonal Rainfall Predictions for Benue State, Nigeria (Source: NIMET)

State	City	Longitude	Latitude	Onset date	Season end	Season length days	Annual Rainfall (mm)
Benue	Gboko	09.00	07.32	11/4/2015	26/11/2015	231	1484
	Markurdi	08.54	07.73	1/5/2015	17/11/2015	200	1068
	Otukpo	08.14	07.20	9/4/2015	27/11/2015	233	1519
	Aliade	08.48	07.30	10/4/2015	26/11/2015	231	1490
	Oju	07.91	07.38	11/4/2015	26/11/2015	229	1466
	Ugbokpo	07.88	07.66	15/4/2015	23/11/2015	223	1388
	Wanunne	08.89	07.57	13/4/2015	24/11/2015	225	1413
	Anyiin	08.58	07.71	15/4/2015	23/11/2015	222	1375
	Okpoga	07.80	07.04	7/4/2015	29/11/2015	236	1567
	Orokam	07.55	06.97	7/4/2015	30/11/2015	238	1589
	Egumale	07.96	08.80	5/4/2015	1/12/2015	242	1643
	Idekpa	07.93	07.23	10/4/2015	27/11/2015	233	1510
	Obagaji	07.91	07.88	17/4/2015	21/11/2015	219	1330
	Kyado	09.72	07.65	14/4/2015	23/11/2015	224	1391
	Zaki Biam	09.61	07.51	13/4/2015	25/11/2015	227	1430
	Katsina Ala	09.28	07.16	9/4/2015	28/11/2015	234	1531

Table 4. 2014 Seasonal Rainfall Predictions for Benue State, Nigeria (Source: NIMET)

Year	City	Longitude	Latitude	Onset date	Season end	Season length days	Annual Rainfall (mm)
2014	Gboko	09.00	07.32	1st April	3rd Dec	238	1579
	Markurdi	08.54	07.73	20th April	22nd Nov	203	1046
	Otukpo	08.14	07.20	30th March	4th Dec	240	1618
	Aliade	08.48	07.30	1st April	3rd Dec	239	1585
	Oju	07.91	07.38	2nd April	3rd Dec	237	1559
	Ugbokpo	07.88	07.66	5th April	30th Nov	231	1472
	Wanunne	08.89	07.57	4th April	1st Dec	233	1499
	Anyiin	08.58	07.71	6th April	30th Nov	230	1457
	Kyado	09.72	07.65	5th April	30th Nov.	232	1475
	Zaki Biam	09.61	07.51	3rd April	1st Dec	234	1518
	Katsina Ala	09.28	07.16	30th March	4th Dec	241	1632
2013	Gboko	07.32	09.02	23rd April	10th Nov	202	1000
	Markurdi	09.00	08.00	21st April	17th Nov	210	1189
	Otukpo	07.18	08.13	12th April	16th Nov	219	1217
2012	Gboko	09.02	07.32	7th April	11th Nov	216	1422
	Markurdi	09.00	08.00	16th April	11th Nov	204	1227
	Otukpo	08.13	07.18	5th April	11th Nov	218	1466
2011	Gboko	07.32	09.02	25th April	6th Nov	192	1009
	Markurdi	09.00	08.00	12th April	9th Nov	209	1242
	Otukpo	07.18	08.13	13th April	9th Nov	207	1209

Table 5. Summary of 2011-2015 SRPs in terms of agro-ecological zones (Source: Nigerian Meteorological Agency – NIMET)

Agro-Ecological Zones	States covered	Onset dates	Cessation Dates	Length of Growing (Planting) Seasons (in days)	Seasonal Rainfall Amount (mm)
Swamp Forest	Lagos, Bayelsa, Rivers, Akwa Ibom, Cross River, etc	24 Feb - 30 March	4 - 11 November	227 - 266	1200 - 2700
Tropical Rain Forest	Ogun, Ondo, Osun, Edo, Imo, Delta, etc	7 March - 3 April	3 - 16 November	220 - 247	1200 - 2700
Guinea Savannah	Kwara, Kogi, Niger, Benue, Abuja, Taraba, Oyo, Enugu	23 March - 2 June	5 - 12 November	163 - 233	900 - 1700
Sudan Savannah	Bauchi, Yola, Gombe, Kano, Kaduna, Plateau, etc	9 May - 10 June	16 Oct - 7 November	129 - 183	800 - 1100
Sahel Savannah	Borno, Sokoto, Zamfara, Katsina, Kebbi, Adamawa	15 June - 30 June	3 - 22 October	93 - 150	300 - 800

In a bid to provide an aggregate view of the impact of global warming and El Nino on rainfall as an important weather and climate variable for the study period of 2011-2015, Table 5 shows the summary of the 2011-2015 SRPs in terms of Agro-Ecological zones in Nigeria.

The data show decreasing rainfall from the Swamp Forest region of Nigeria to the Sahel Savannah region; a reflection of the growing impact of desertification on Northern Nigeria. The Adum-Aiona Community is in the Guinea Savannah region with SRP of 900-1700 mm. Overtime, the data indicates that the onset dates are becoming late while the cessation dates are getting early, all pointing to the growing influence of climate vagaries on the environment. To survive, mitigation and acclimatization techniques are required by the rural farmers in Adum-Aiona just as in other rural African communities.

The data is a confirmation that human impacts such as deforestation, fossil fuel burning, among others account for carbon dioxide emission into the atmosphere that in turn result in climate change harsh conditions such as late onset and early cessation of rains, flash flooding, gully erosion, coastal erosion, caked soil, loose of soil nutrients, just to mention a few. The resultant effect is depletion in agricultural yield with dire implications for food insufficiency and insecurity, hunger, social tensions, unemployment, kidnapping and terrorism.

The proposed Climate Change Response System (CCRS) is promising for re-orientating rural dwellers on ecologically-friendly behaviours such as afforestation, discouraging bush burning practices, and use of clean energy for cooking. It also facilitates the ability of rural dwellers to adjust to weather and climate vagaries as well as mitigate their negative impacts by embracing climate-resilient agriculture. CCRS relies on its creative art-modelled sensitization campaign sub-system for achieving the trio of environmentally-friendly behaviours, adaptation and mitigation strategies. The use cases (tasks) of CCRS are mechanisms that reposition rural African dwellers for bracing up to the realities of climate unpredictability: Sensitization and education of farmers, for example, will not only promote environment-friendly behaviours but will teach them adaptation and mitigation techniques; the climate change insurance policy will encourage the introduction and implementation of weather insurance policy to safeguard against climate change-related agricultural losses; Dams and river basins revitalization will harness surface water for irrigation farming as complement of rain-fed agriculture; Harnessing of underground water through digging of community wells and boreholes will augment traditional techniques for adaptation and mitigation, hence promoting domestication and ownership of CCRS; Extension services will ensure that farmers are enlightened on climate-resilient agricultural practices and inputs; Packaging and dissemination of meteorological forecasts through formal institutions (extension services) and informal institutions (worship places, town hall meetings, and age-grade group meetings, among others) will promote proactive actions by farmers and all stakeholders in combating the menace of climate change.

4.2. Evaluation Threats

It is not impossible that an expanded evaluation of the respective modules of the CCRS could unveil fresh dimension of the impact of global warming and El Nino on rural African communities like the Adum-Aiona community. In any case, the seasonal rainfall prediction data used for our evaluation of the existential threat posed by climate change to human livelihoods are real-life operational data obtained from the Nigerian Meteorological Agency (NIMET). NIMET over the years have built sufficient capacity in availing climate, weather, and water information for safety and sustainable development which encompasses information of expected rainfall pattern that is valuable for planning, decision making and execution of socio-economic development projects. As a result, they can make objective annual prediction that impact various sectors such as agriculture, aviation, transportation, water resources, telecommunication, and construction, among others. Hence, NIMET's views can be taken seriously (Host et al., 2000; Runeson, 2003; Sauro, Kindlund, 2005; Svahnberg et al., 2008). In addition, only 5-year seasonal rainfall predictions were used in the assessment, which has the potential of constraining the statistical significance of study findings (Nielsen, Landauer, 1993; Turner et al., 2006). In any case, the outcome of the survey is indicative that the combined effects of global warming and El Nino have impacted significantly on rainfall patterns in Africa and rural Africa in particular with evidence of early cessation and late onset of rains. This underscores the need for updated adaptation and mitigation techniques for Africans to survive environments imposed by climate change. In our view, this is a significant result since at this juncture in the study, the key objective is to secure an impression of the impact of climate change on livelihoods in rural Africa and how a climate change response system can aid adaptation and mitigation. Hence, in spite of the limited seasonal rainfall prediction data used in the evaluation, there is sufficient ground to infer that climate vagaries affects human livelihoods and a response system for climate change has the potential to strengthen adaptation and mitigation. We can thus generalize that the model-driven climate change response system is effective for instituting ecologically friendly behaviors and driving climate-resilient means of livelihood among both rural and urban African folks.

5. Recommendations

To cushion the challenge of climate change, CCRS is inbuilt with mechanisms for behaviour change, adaptation and mitigation. With these measures, it is hoped that the adverse impact of El Nino as expressed in unfavourable temperatures and rainfall will be reduced. Based on the study outcome, we advise that the following measures be put in place to help rural African dwellers to cope with the negative impact of climate vagaries on livelihoods:

1. Sustained sensitization and education of rural dwellers on dangers of environmentally unfriendly activities such as deforestation and indiscriminate burning of fossil fuel as exemplified in the Creative arts model. Formal method (extension services) and informal methods (worship places, age groups, town hall meetings, etc.) could be harnessed.
2. Extension services should be revamped at all levels of government to reach out to farmers with latest information on new farming techniques and inputs that promotes climate-resilient agriculture.
3. In the light of established agricultural impact of climate vagaries, the scope of extension services should be expanded to include seasonal rainfall predictions (SRPs) by meteorological agencies. The SRP information will guide farmers in decision making.
4. There is need for agricultural policy consistency particularly with respect to construction and maintenance of dams and river basins for irrigated farming to complement the dominant rain-fed agriculture in Africa.
5. The various traditional approaches adopted by locals in the past for adapting and reducing climate change impact should be integrated in any climate change response system for communities to domesticate and take ownership of such system.
6. Government and the private sector should start thinking of implementing climate change insurance policy as safety net for those who may suffer agricultural loses as a result of the weather vagaries.
7. Appropriate pricing for kerosene, cooking gas, and petrol should take into account the purchasing power of the rural poor. This way, alternative to the use of firewood is formulated, discouraging deforestation and strengthening afforestation drive.

6. Conclusion

We have provided both computational and artistic impressions of the effect of El Nino and climate vagaries on rural Africa using the Adum-Aiona community as case study. In the face of growing impact of El Nino on livelihoods of rural Africans, measures to promote afforestation, shift to clean energy and climate-resilient agriculture and construction cannot be overemphasized. El Niño gives rise to global changes in rainfall and temperatures. Simulations and measurements have shown that climate change is contributing to extreme El Niños in recent years with visible impact on human lives as evident in humanitarian crisis in the horns of Africa – Ethiopia and Eritrea. It confirms the sentiment that the most affected are developing countries bordering the Pacific Ocean whose means of livelihood are agriculture and fishing. This study has provided empirical evidence to the effect that climate change threats on man and his means of livelihood are real. The study equally designed a climate change response system for aiding climate change adaptation and mitigation. We concluded by recommending a number of measures that will promote ecologically friendly behaviours and protect rural African dwellers from the negative impacts of climate change. Future research is needed to institute and strengthen weather-conscious insurance policy for African farmers as a mitigation strategy for climate-induced loss of agricultural products.

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