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Original article

Simulating the effects of climate change and afforestation on wind power potential in Nigeria

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ABSTRACT

The objective of this study is to determine the effects of global warming and future afforestation on wind power potential in Nigeria. A series of multi-year simulations of a regional climate model (ICTP-RegCM3) for 1981–2000 (baseline) and 2031–2050 (future with elevated CO_2 under A1B emission scenario) periods, generated from a previous experimental study on the impacts of afforestation on the region's climate, were used. In the study, land-use patterns produced from seven different hypothetical afforestation scenarios were then used as boundary conditions in RegCM3 to simulate various future climate scenarios. Four of these options assumed random (i.e. 100, 75, 50 and 25%) afforestation over the country, while the other three assumed zonal (i.e. North (RNZ), Middle-belt (RMZ), and South (RSZ)) afforestation. Wind power density varied with season across the country. The north-eastern regions had the highest potential for wind power harvesting with the peaks (120 W/m^2 at 10 m; 260 W/m^2 at 100 m hub heights) during the dry season. A rise (+10 to +30%) in wind power over most parts of the country during the wet season (May to July) and a decrease (−10 to −25%) in dry season (October to January) were projected. Random afforestation generally suggested negative significant impacts (25–100%) on future wind power over the country. However, zonal afforestation had positive ($\leq$ +20%) impacts upwind the afforested zone but negative ($\approx$ −100%) over the afforested zone. Future RSZ afforestation option was found to enhance the wind power harvesting potential of the north-eastern regions of Nigeria.

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Introduction

The greatest challenge facing Nigerians today is the ailing energy sector that is over-dependent on hydropower and fossil energy sources. According to Akuru and Okoro [1], the electricity consumption per capita in Nigeria is about 100 kWh (compared to 4500 kWh, 1934 kWh and 1379 kWh in South Africa, Brazil and China, respectively) while about 60% of the population (with majority in the rural areas) have no access to the national grid. The authors submitted that hydropower (supplying about a third of electricity supply) is habitually under pressure, especially in the dry seasons when there are drastic reduction in water available in dams; hence, sole reliance on renewable energy source is unnecessary. To worsen the poor development of the power sector in Nigeria, a databank on renewable energy investments is either unavailable or inaccessible.

Wind energy stands out to be one of the most promising new sources of electrical power in the near future [2,3]. Extraction of power from wind on a large scale has thus become a recognized industry which holds great potential and increasingly playing a key role in energy supply globally; its very clean nature, non-greenhouse gas (GHG) emissions and infinite availability further support its utilization for electricity generation [4,5].

Wind is a natural phenomenon related to the movement of air masses that is caused primarily by the differential solar heating of the earth's surface [6]. Wind turbine converts wind energy into electrical energy, which is later injected into the electricity supply system. Direction of wind movement is determined by the interaction of pressure gradient, Coriolis effect and friction (surface). Friction drag of Earth's surface (e.g. trees and tall buildings) slows wind down (and cause turbulence) and reduces Coriolis effect. The impact of surface friction extends to only about 1000 m; at higher atmosphere most winds are geostrophic. As such, wind speeds increase with height, and the higher a turbine is, the more electricity it is likely to be produced. The location of a wind turbine is therefore crucial for maximising its overall performance. A good

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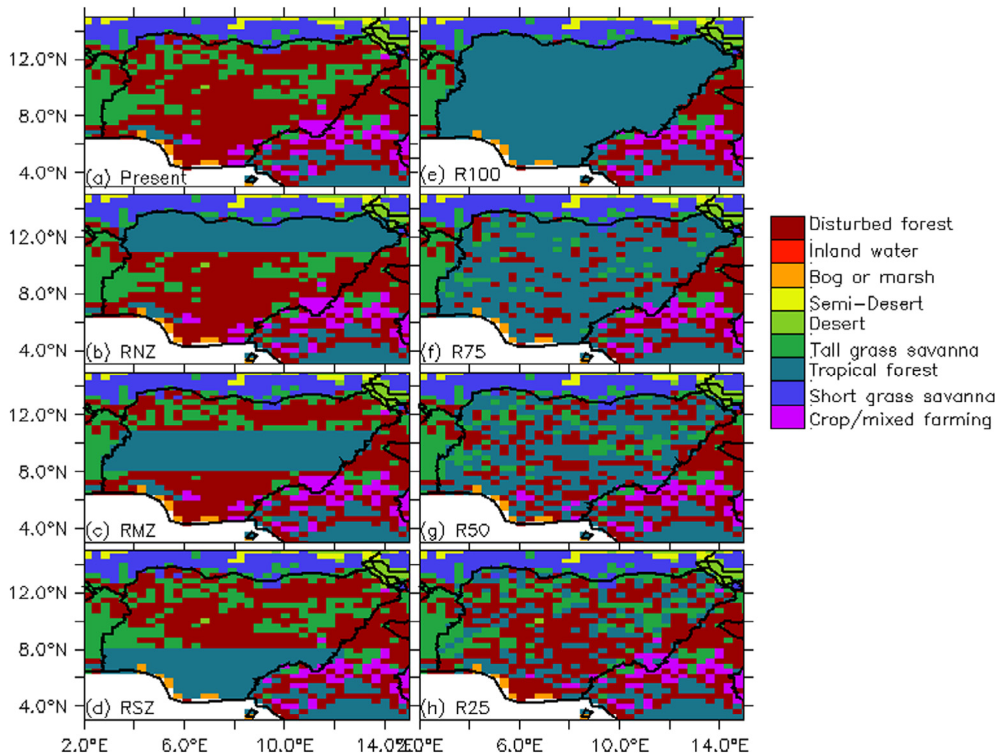

Fig. 1. Land-use patterns used in this study for the different random and zonal reforestation scenarios (Adapted from Abiodun et al. [26] or [27]).

Table 1
Present (1981–2000) and future (2031–2050) change in annual mean surface minimum temperature (TMI; °C), maximum temperature (TMX; °C), and wind speeds (WSP; m/s) at 10 and 100 m heights over the South, Mid-belt and North zones of Nigeria.

Zone		Parameters			
		TMI	TMX	WSP (10 m)	WSP (100 m)
North	Present mean	24.8	28.6	4.60	6.39
	STD	0.51	0.57	0.48	0.64
	Future mean	26.4	30.3	4.64	6.45
	Future change	1.6*	1.7*	0.04	0.06
	% change	6.68*	5.64*	0.95	0.94
Mid-belt	Present mean	23.8	26.9	3.80	5.28
	STD	0.50	0.52	0.35	0.58
	Future mean	25.0	28.3	3.93	5.46
	Future change	1.2*	1.5*	0.13	0.18
	% change	6.07*	5.19*	3.42	3.41
South	Present mean	22.8	25.1	3.30	4.59
	STD	0.42	0.48	0.25	0.45
	Future mean	24.0	26.3	3.32	4.61
	Future change	1.2*	1.2*	0.02	0.02
	% change	5.33*	4.74*	0.50	0.43

STD = Standard deviation.
% change = Percentage future change.
* significant i.e. (|future change| > standard deviation of the present mean).

understanding of wind speed pattern is therefore very critical before installing any wind energy conversion system.

There is also global concern about the negative impacts of climate change, thus calling for reduction of GHG emission (in order to explicit the challenges that a country relying on fossil fuel has to face). The potential climate change effects and the continued apprehensions about nuclear power utilization around the world, have resulted in strong campaign for renewable energy production and utilization, particularly in the developing nations of the world [7]. Renewable energy sources, which are known to be technologically efficient, environmentally compatible and relatively cost competitive, offer viable alternatives to the provision of power in rural areas [8,9]. Interestingly, Nigeria is endowed with sufficient renewable energy resources to meet its present and future energy requirements, as well as needed to complement its current oil-dependent economy [10]. However, there is little or no encouraging investment in renewable energy resources in Nigeria as implementation of the Renewable Energy Master Plan (REMP) remains a paper work [10].

A large number of studies had comprehensively documented wind speed patterns, characteristics and wind energy potential in Nigeria [10–23]. It was revealed in these studies that mean wind

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