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2 **Tropical forest: a potential resource for climate**
3 **change mitigation in Ghana.**

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13 **ABSTRACT**
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Climate variability and change has become a global phenomenon with many countries including Ghana working hard to mitigate the effect or develop strategies for adaptation. However, tropical forest has been identified to have the capacity to mitigate the impact of climate change and improve the general environment. The forest plays a critical role in the climate system, hydrology and the carbon cycle, and provide livelihood for over 2.5 billion rural dwellers in developing countries. This article therefore highlights the importance of tropical forest in addressing the challenges of climate change and the need for policy makers, stakeholders and the general public to seriously adopt positive approach to the management of forest resources. The article was carried out through extensive review of literature, official reports and policy documents. The paper outlines the threat of climate change, the state of Ghana's forest and climate, and the role of the forest to mitigate climate change. It also highlights the socio-economic benefits of the forest in mitigating the changing climate. The documents reviewed showed that the state of Ghana's forest has dwindled over the years through anthropogenic activities and the climate is also changing. It was also established that trees can remove a substantial amount of CO₂ from the atmosphere for storage. The paper concludes with recommendations for the preservation and regeneration of the tropical forest for the purpose of mitigating the effect of climate change in Ghana.

15
16 *Keywords: climate change, tropical forest, forest resources, climate variability, Carbon-*
17 *dioxide emissions, deforestation, mitigation*
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20 **1. INTRODUCTION**

21

22 The issue of climate change has become a global phenomenon with its attendant
23 consequences. The search for food, clothing, shelter, improved standard of living as well as
24 technology and energy use has altered the atmosphere negatively through the introduction
25 of Greenhouse Gases (GHGs) in higher concentrations which cause climate change [1].
26 The rising concentrations of the GHGs mainly CO₂ in the atmosphere has been attributed
27 mainly to anthropogenic activities such as the extensive use of fossil fuels like coal, oil and
28 gas, deforestation, burning of vegetation, loss of wetlands, agriculture among others. The
29 GHGs are mainly carbon dioxide (CO₂), methane (CH₄), water vapour (H₂O), nitrous oxide
30 (N₂O) and ozone (O₃) and these create a thick blanket in the atmosphere to prevent infrared
31 radiation (heat) from escaping thus resulting in global warming [2, 3]. There is high evidence
32 of global warming with Africa being more susceptible to rising land temperature [3] and this
33 will affect water resources, agriculture, health and the socio-economic development of many
34 nations [42]. Due to the negative impact of climate change, many international bodies are
35 therefore making frantic effort to curb the rising global temperature.

36 One of the long term goals of the 2015 Paris Agreement was to keep the increasing global
37 average temperature to well below 2°C above pre-industrial levels and possibly limit the
38 increase to 1.5°C leading to a net zero GHG emissions. This will significantly minimize the
39 risks and the impacts of climate change. One of the key measures considered was the forest
40 and its restoration. The forest, apart from its ability to sequester carbon, serves as food,
41 water purification, shelter, energy among others for many vulnerable people in developing
42 countries. Despite its importance, research has shown that the forest has over the years
43 suffered from severe deforestation, degradation and desertification. Such disturbances have
44 been a major concern and the European Union (EU) has made commitment to end
45 deforestation and forest degradation possibly by 2030 globally with over 3 billion euros
46 invested in addressing deforestation through Reduction of Emissions from Deforestation and
47 forest Degradation (REDD+) programme [4]. The Sustainable Development Goal 2015, goal
48 15.2 also demands the implementation of sustainable management of all types of forests,
49 halt deforestation, restore degraded forests and increase afforestation and reforestation by
50 the year 2030. It is estimated that 13 million hectares of forests are lost annually while
51 continuous degradation of drylands has led to the desertification of 3.6 billion hectares and
52 this affect poor communities negatively [5].

53 The REDD+ programme has become a major component of the Paris Agreement in Article 5
54 which states that (1) "Parties should take action to conserve and enhance, as appropriate,
55 sinks and reservoirs of GHGs" as indicated in Article 4, paragraph 1(d), of the Convention,
56 including forests. Also, parties are encouraged to take action to implement and support
57 agreement under the Convention to reduce emissions from deforestation and forest
58 degradation, enhance forest carbon stocks in developing countries and adopt an integral
59 approach towards sustainable management of forests [6]. Afforestation, reforestation and
60 forest restoration are therefore measures that can mitigate the changing climate. This article
61 therefore emphasize on the importance of the tropical forest and the need for policy makers,
62 stakeholders and the general public to seriously adopt positive approach to the management
63 of forest resources. The article was carried out through extensive review of literature, official
64 reports and policy documents to establish the importance of the tropical forest for addressing
65 climate change.

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68 2. THE STATE OF GHANA'S FOREST

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70 The National Environmental Policy 2014 has recognized environmental challenges including
71 land degradation, deforestation and desertification as one of the major drivers of climate
72 change and therefore seeks to ensure a climate resilient and climate compatible economy in
73 Ghana. The Sustainable Development Goal 2015, goal 13 demands an urgent action to
74 combat climate change and its impacts. This is a clarion call and Ghana cannot be left out.
75 **Food and Agricultural Organization (FAO)** [7] estimated that an alarming rate of 13 million
76 hectares of forest is lost globally each year from 2000 – 2010 through deforestation. In sub-
77 Saharan Africa, agricultural productivity has mainly centered on widening the area under
78 cultivation [8] and this has also influenced deforestation and forest degradation. About 70-
79 80% of the forest is lost through agricultural expansion [9] in addition to other factors such as
80 population growth and other land use change. According to [10] Nigeria lost about 90% of its
81 primary forest through logging, mining and agricultural plantations and the situation is not
82 different from Ghana.

83 In Ghana, it is estimated that 2% (135, 000 ha) of the forest cover is lost annually and about
84 60% of the forest cover is lost since 1950 [11]. Ghana's forest of about 8.2 million hectares
85 at high forest with a transition zone of about 1.1 million hectares and savanna vegetation
86 covering about 14.7 million hectares between 1900 and 1950 has been reduced to 4.2
87 million hectares [12]. An average of 46 000 hectares of Ghana's closed forest is lost annually
88 from 1990-2010 and arable land expanded from 2.70 million hectares in 1990 to 4.70 million
89 hectares in 2013 [13]. Recently the Forestry Commission impounded about 19 trucks
90 carrying illegal sawn lumber including Rosewood in the Eastern, Volta and Western regions
91 and this illegal activities have been part of the forest degradation activities [14]. **A speech by**
92 **Prof Mrs. Esi Awuah**, former Vice Chancellor of the University of Energy and Natural
93 Resources, also revealed that "between 2005 and 2010, the rate of Ghana's deforestation is
94 about 2.19 percent per annum, being the sixth highest deforestation rate globally for that
95 period. The Forestry Commission also estimated that the cost of environmental degradation
96 is between 5-10% of GDP as at 2010 with about 63% from the forest sector [15].

97 **The United Nations Development Programme (UNDP)** has estimated that 1.6 billion people
98 depend on the forests for their livelihoods for various reasons [3]. Cairns and Meganck [16]
99 argued that tropical forests are being harvested at a rapid pace and the use of the forest to
100 sequester carbon will fail unless the economic, social and political needs of the local people
101 are addressed. The consistent degradation of forest resources will heighten atmospheric
102 carbon concentration causing climate variability such as changes in temperature and rainfall
103 pattern which causes floods, droughts, and alter watershed and biochemical processes [17].
104 Research has also revealed that large-scale and regular burning of vegetation in the tropics
105 also add a great deal of gases, inter alia, carbon dioxide, nitrous oxide, carbon monoxide,
106 methane in addition to aerosols to the atmosphere [18]. Northern Ghana experiences
107 rampant bush burning annually and this also affects the vegetation and soil fertility in the
108 regions. According to [19] incessant fires also affect the growth of woody vegetation. Whelan
109 [20] also affirms that, the burning of forest causes death of individual trees, loss of soil
110 nutrients, changes the surface soil organic layers and landscape among others. Ghana's
111 Readiness Preparation Proposal (GRPP, 2015) also identifies the principal drivers of
112 deforestation and forest degradation as agricultural expansion (50%), wood harvesting
113 (35%), population and development pressures (10%), mining and mineral exploitation (5%).
114 According to the [21] Ghana's economy has for a long time depended heavily on its natural
115 resources such as timber, cocoa, minerals among others which contributes about 48% to
116 GDP, 90% of foreign exchange earnings and 70% of total employment, and this may partly
117 be responsible for the rapid degradation of the forest resources. The degradation of **forest**
118 also comes with cost to the nation. During the fifth Annual Environmental and Natural

119 Resource Summit in Sunyani, it was revealed that the cost of forest depletion, agricultural
120 soil degradation and environmental health damage in Ghana by 2010 was estimated at 3.7%
121 of Gross Domestic Product (GDP) [22]. This therefore calls for stringent measures to
122 address issues related to deforestation and forest degradation.

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124 **3. DEFORESTATION – A DRIVING FORCE OF CLIMATE CHANGE IN GHANA**

125 Deforestation has become one of the major challenges to climate change especially in Africa
126 where timber and other forest resources are overexploited for economic gains. According to
127 [1] deforestation is said to be the second most dreadful agent that causes climate change
128 apart from the use of fossil fuels. The continues deforestation and forest degradation will
129 therefore intensify climate change events leading to drought, floods, extreme weather
130 conditions, erratic rainfall patterns, sea level rise among others. The annual contribution from
131 deforestation and changing land use is 23% of the total emission of CO₂ to the atmosphere
132 [23].

133 Conversion of forests to agricultural land is estimated to be 13 million hectares annually and
134 this releases carbon stored in trees as CO₂ emissions into the atmosphere [24]. It is also
135 estimated that large-scale commercial agriculture is responsible for 40% of deforestation,
136 subsistence agriculture which provides livelihood to many poor households in Africa
137 including Ghana account for 33% as well as infrastructure and urban development including
138 mining account for about 27% in the tropical regions with high population growth [13].
139 According to [7] deforestation has resulted in the emission of CO₂ between 4-12% globally
140 and 4-12 billion tons of CO₂ equivalent annually of which 9% are all attributed to agricultural
141 land clearing. Additionally, the annual net global deforestation is said to contribute about 2
142 gigatons of carbon emissions to the atmosphere. Carbon loss from conversion of terrestrial
143 ecosystems to agriculture ranges from 21 to 46% [25]. Carbon released into the atmosphere
144 from tropical forest harvesting amount to about 11 to 3.6 pentagrams of carbon annually [26]
145 and this is likely to have a devastating consequences due to such anthropogenic activities.
146 Excessive CO₂ in the atmosphere resulting in climate variability and change will affect
147 agriculture output, energy delivery, food security and the socio-economic development of
148 many nations. The impacts will hard-hit the very poor in society who depends on
149 environmental goods and services for their survival.

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151 **4. CARBON-DIOXIDE EMISSIONS - THE ENEMY OF CLIMATE CHANGE**

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153 The sun's energy is the life sustaining resource that drives the earth's climate and weather
154 [27] and the main source of life for plants and animals. Naturally, the climate system is
155 designed to be self-sustaining through a balanced reaction of gases that envelope the
156 universe especially Oxygen (21%) and Carbon dioxide (0.03%). The relationship that exists
157 between plants and animals also play a key role in the maintenance of the self-sustaining
158 climate systems. Plants use CO₂ to produce food and release oxygen as a by-product
159 through photosynthesis while humans/animals use oxygen and give out CO₂ through
160 respiration. Plants and animals are therefore supposed to co-exist harmoniously to sustain
161 the climate systems but due to the overexploitation of the natural forest and other activities,
162 such harmonious co-existence has been affected leading to imbalances of certain chemicals
163 such as CO₂ in the atmosphere causing changes in the atmospheric parameters.

164 The roots, trunks, stems, branches and leaves of trees store carbon removed from the
165 atmosphere making the forest an indispensable component of the carbon-energy cycle.

166 When the leaves fall and plants die, the carbon is transferred into the soil for keep through
167 decomposition by micro-organisms. This basically implies that the more forest we have, the
168 more carbon will be removed from the atmosphere for storage and vice versa. Unfortunately,
169 overexploitation of the natural forest and anthropogenic activities such as deforestation,
170 forest degradation, poor land use management, agriculture and illegal forest mining over the
171 years have altered the natural cycle of the carbon in the atmosphere [1]. These
172 anthropogenic activities among others have partly been responsible for the changing climate
173 through the release of certain Greenhouse gases (GHGs) such as carbon dioxide (CO₂),
174 methane (CH₄), water vapour (H₂O), nitrous oxide (N₂O), ozone (O₃) and halocarbons [3].
175 The higher concentration of the GHGs especially CO₂ which is a good absorber of infrared
176 radiation, creates a thickening layer of pollution above the earth, trapping in heat which
177 eventually causes global warming [25, 28] and climate change. According to Houghton et
178 al. (1990) cited in [23], CO₂ alone contributes about 55% to global warming. It is estimated
179 that a km² of tropical forest is made up of about 25,000 biomass (existing trees) which
180 contains about 12,000 tonnes of carbon and 2/3 of this amount is converted into CO₂ [29].
181 This therefore shows how important the forest is in maintaining a sound environment and
182 averts or mitigate the challenges of climate change.

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184 **5. THE ROLE OF FOREST IN CLIMATE CHANGE MITIGATION**

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186 The forest in Ghana has suffered drastic decline over the years through resettlement,
187 clearing of land for farming and building projects, illegal chainsaw milling and logging, wood
188 fuel and charcoal production in addition to bush burning, infrastructural development and
189 mining activities especially in the three regions of the north [30]. The forest is known for its
190 ecosystem services, biodiversity conservation and maintenance of its cultural heritage for
191 generations and forms a major component of human existence. The forest plays a vital role
192 in controlling CO₂ concentration in the atmosphere and global hydrological cycle through the
193 mediation of surface runoff, groundwater recharge and GHG mitigation strategies [7].
194 Through photosynthesis, the forest absorbs carbon from the atmosphere thus reducing the
195 concentration of CO₂ in the atmosphere. CO₂ is also stored in the various parts of the plants
196 and the more plants we have, the more CO₂ is extracted and stored. According to [31]
197 every tree stores about 50% of carbon which is extracted from the atmosphere and for every
198 tonne of carbon stored, 3.667 tons of CO₂ is taken from the atmosphere. Lawrence [32] has
199 also estimated that old-growth tropical forests store between 120-400 tons of carbon per
200 hectare of land. Nair *et al.* [33] also reported that agro-forestry systems like inter-cropping
201 with about 50 trees/ha can store 100 to 147 tons of CO₂ equivalent/ha in semi and arid
202 lands. An FAO document on building greener cities also suggests that mature trees can
203 absorb up to 150 kg of CO₂ per year [34]. The forests contain twice as much carbon as the
204 atmosphere and metabolize more than 14% of atmospheric carbon each year [35]. These
205 facts, unequivocally, make the forest an indispensable resource for the extraction and
206 storage of atmospheric carbon to mitigate climate change.

207 Apart from the forest serving as carbon sequester, it also provides a cooling effect to reduce
208 the heat within the environment. Boanoua *et al.* [36] has observed a year-round cooling of
209 0.8°C in the tropical areas of Africa due to increased vegetation cover. According to [37]
210 shading and vegetation cover reduces the mean and variance of groundwater
211 temperature. FAO document on building greener cities also suggests that trees located at
212 certain areas can help cool the air between 2-8 °C which will influence the heat island effect
213 in urban cities [34]. The cooling effects of protecting and restoring forest cover in the tropics
214 may be even greater than originally estimated.

215 Deforestation and forest degradation therefore inhibit the forest from performing its
216 multipurpose functions. All the carbons stored in the forest plants find their way back into the

217 atmosphere when the forest is cleared and burnt. The ability of the forest to remove CO₂ is
218 denied thus increasing the concentration of carbon in the atmosphere. Burning of the forest
219 also incapacitate the trees from absorbing CO₂ in the atmosphere. Deforestation and forest
220 degradation through burning therefore enhance the concentration of CO₂ in the atmosphere
221 leading to global warming and climate change. **There are various proposed measures for**
222 **addressing climate change. Among these are the capture and storage of CO₂ in deep**
223 **underground and ocean wells, reduction in the use of fossil fuel, shift to renewable energy**
224 **sources among others. These measures for addressing climate change are possible but are**
225 **quite expensive which a developing country like Ghana can hardly afford. The tropical forest**
226 **if expanded and properly managed will therefore play a key role in mitigating the threat of**
227 **climate change.**

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229 **6. THE SOCIAL AND ECONOMIC BENEFITS OF THE FOREST**

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231 The social and economic benefits of the forest cannot be overemphasized. The forest, apart
232 from maintaining ecological balance, provides environmental goods and services to support
233 the livelihood of millions of poor people in developing countries. The forest provides
234 medicine, shelter, energy, food, and clothing; enhance soil fertility, water quality and improve
235 soil structure and texture among others. It is estimated that the forest provide livelihoods to
236 about 1.6 billion people and a home to over 80% of all terrestrial species of animals, plants
237 and insects [5]. However, lack of economic opportunity, poverty and hunger compel poor
238 people in low income countries to exploit the natural resources around them especially
239 women. Sunderland et al. [38] observed that, women lack the opportunity to generate
240 adequate income as men even though they tend to commercialize the forest products better
241 than men.

242 Deforestation is directly linked to poverty levels in that as deforestation increases in
243 developing countries due to population explosion, demand for agriculture lands and
244 unsustainable forest resource exploitation also increase. However, developed nations forest
245 keeps increasing while population decreases [13]. Many governments in the continent also
246 exploit the raw forest timber and other forest products to generate foreign exchange, even
247 though, some hardly re-invest part of the proceeds to restore the lost forest. In Ghana, the
248 forest sector generated about US\$283.2 million in 2013 through export [13]. According to
249 [39] about 40% or 2.4 billion people living in developing countries depend on wood fuel for
250 cooking and these are mainly women. It is estimated that about 88% of household energy in
251 Ghana for cooking comes from wood fuel and charcoal [40]. The savannah zone with low
252 forest resources also provides about 70% of Ghana's total annual firewood and charcoal
253 requirement estimated at 16 million m³ [41]. The situation is not only limited to the north but
254 across the entire country. It is true that the continuous dependence on the forest for energy
255 and income through various means have adversely affected the forest cover. However, due
256 to the economic circumstances of many rural dwellers that depend on the forest, appropriate
257 policies could be developed to specifically assist these rural dwellers to ease the pressure
258 on the forest. The adoption of urban and peri-urban forestry will also improve nutrition and
259 food security, ensure climate change mitigation and possible adaptation as well we as
260 providing ecosystem services. According to FAO, trees in cities could bring substantial
261 benefits such as provision of food and nutrition, safety of urban biodiversity, mitigate urban
262 pollution, climate change, regulate urban water and air flows, sustain conducive environment
263 and increase esthetics, physical and mental health and property value of the cities [34].
264 However, the underlying cause of illegal logging, felling of trees for charcoal production and
265 wood fuel as well as poor agricultural expansion must first be addressed to reduce
266 deforestation and forest degradation. With proper investment and value addition to the forest
267 products, the challenges of deforestation and forest degradation could be minimized.

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7. CONCLUSION AND RECOMMENDATIONS

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This article has outlined the role of the forest in mitigating climate change and also provides additional benefits to the economy and society as a whole. The importance of the forest to mitigate climate change through CO₂ sequestration cannot be overemphasized. Carbon dioxide which is the major driver of climate change is a threat to the environment and the forest as a carbon sink can play a key role to avert the negative consequences of the changing climate. It has already been established that the forest has the capacity to remove substantial amount CO₂ from the atmosphere and clearing such forest resources will cause climate variability which may have serious consequences on water resources, food production, energy and socio-economic development of many African countries.

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Besides, the forest provides many benefits to the socio-economic and cultural existence of mankind. Human life and the climate without doubt depend on the forest. The saying that “the day the last tree will die, the last man will also die” indicates that our human life is actually linked to nature. Adopting intensive afforestation and reforestation globally and proper land use and agricultural management, efficient energy use, and frantic effort to prevent deforestation and land degradation could be the way forward in mitigating the effect of climate change. Let’s therefore protect the forest for posterity. The following are suggested recommendations to promote the forest resources for climate change mitigation in Ghana.

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1. **Eliminate Poverty** - Poverty is indeed the underlying cause of forest and environmental degradation. Charcoal production, illegal forest mining and other anthropogenic activities stem from people’s effort to make ends meet. An alternative means of livelihood will reduce if not eliminate the rate of deforestation in Ghana.

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2. **Empower** local communities - chiefs, opinion leaders and assembly men in communities can effectively manage the forest around them if given the mandate to do so. This is a shared responsibility.

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3. **Develop and implement** REDD+ Policy - proper adaptation and implementation of the REDD+ will result in socio-economic and environmental benefits leading to the mitigation of climate change, promote economic growth, job creation, livelihoods enhancement, food security, forests conservation and promotion of sustainable development.

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4. **Strengthen institutional framework** for enforcing the law and management of natural resources.

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5. **Support** woodlots production and agro-forestry - encourage the planting of woodlots for wood fuel and charcoal production including incentives for agro-forestry promotion to free the forest from further encroachment.

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6. **Promote** massive afforestation and reforestation including Urban and Peri-urban tree planting - deliberate planting of trees on all degraded lands including settlements have diversified benefits.

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