

# Biodiversity and the African Savanna: Problems of Definition and Interpretation

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## Abstract

This article examines the various theoretical frameworks and paradigm tools in ecological methods that have been developed to analyze the structure of the African savanna. These are based on the new disequilibrium ecology paradigm, (in contrast to the classical ecology paradigm), which sees the savanna as in continual flux rather than stable equilibrium, and attempt to answer questions concerning socio-environmental relations and environmental change. This topic is crucial to the study of biodiversity and endangered species, as the savanna may be intermediate between forest and desert, and may be the habitat of numerous forest and desert species. The savanna is an ecosystem in its own right and also results from the processes of deforestation, desertification and extinction. The results of the review support the hypothesis that the complexity of the African savanna precludes the usage of classical equilibrium ecology, and the integrated research methods provide a useful basis for the advancement of biodiversity studies for the practical applications of comparative evaluation, measurement of multidirectional change and long-term assessment

**Keywords:** Africa; Biodiversity biogeography; Disequilibrium; Ecology; Savanna

## Introduction

For a study of the relationship between land use and phytogeographical change within a savanna context, from a disequilibrium perspective, the main theme is socio-environmental co evolution. Three main issues must be considered to examine the dynamics and sources of trends in socio-environmental relations. The natural environment, subject to dynamic change, may be interpreted, using the tenets of the disequilibrium school of ecology (which holds that non-linear change and chaotic fluctuations due to socio-environmental interactions offer a more incisive analysis than linear, mechanistic approaches). Human society, also a dynamic and multifaceted phenomenon, may be understood as the interaction of human agency and social structures, in relation to land use. The integration of socio-environmental relationships that are an intrinsic part of both these entities must be the center of our analysis. To analyze and explain adequately such multifaceted issues, with recourse to literature of an often specialized and discipline-conscious nature, requires the acceptance of paradoxes and differing approaches to similar problems. Therefore, the various threads of argument are synthesized to portray the multiplicity and complexity of phytogeographical change. Firstly, various definitions of savanna are considered, as well as the theoretical frameworks developed to describe and analyze savanna ecosystems. This is followed by the analysis of applications of the theoretical frameworks to examples from the African savanna.

## Definitions of Savanna

The environmental context most relevant to the ideas presented above is the tropical savanna. However, there is no definitive agreement about what constitutes savanna vegetation [1], because savannas are highly heterogeneous. Notably, The "word savanna has had an ambiguous career since it entered the English language in the 16th century" [2 - 6]. While "the central concept - a tropical mixed tree-grass community- is widely accepted". The "delimitation of the boundaries has always been a problem" [7]. Therefore, a sensible position is that the savanna represents a "continuum of vegetation types which have trees and grasses as their main constituents", while "acknowledging that at the extremes, the distinction between savannas and woodlands is unavoidably arbitrary" [7].

To attempt a concise definition, savanna is a "tropical vegetation type in which ecological processes, such as primary production, hydrology and nutrient cycling, are strongly influenced by both woody plants and grasses, and only weakly influenced by plants of other growth forms" [7]. This definition is based on that which emerged from the International Responses of Savanna to Stresses and Disturbance (RSSD) Program. To enlarge on this, savanna "designates tropical grassland with scattered trees" and is the "most common tropical landscape unit" [2, 8]. They are "delineated both structurally (specifying a wood/grass composition) and climatically (seasonality of water availability)" [9], and "the structure and dynamics of savanna vegetation is generally expressed as the balance between trees and grasses, and more easily by tree density and distribution" [10].

A relevant is whether the vegetation type referred to as tropical thicket is a type of savanna, as this is a "vegetation formation which does not fit comfortably into the savanna definition" [11]. Tropical thicket is described as vegetation dominated by multi-stemmed woody plants (of course some multi-stemmed woody plants owe their form to cutting for firewood), and in some cases with no grasses, supporting the contention that they are not real savannas. Nevertheless, due to the dynamism of compositional forms, which often sees savannas becoming thickets and vice versa, "in the absence of better understanding of the ecology of thickets, we treat them as a class of savannas rather than as miniature dry forests" [11]. This position is supported by several authors, who include "thicket and shrub" in the vegetation types classified as savanna, and note that thickets, which may be found in "a great diversity of environments, close to the rainforest as well as near the desert edge", are common aspects of coastal savannas [12, 13].

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Savannas cover about half the African continent and one fifth of the land surface of the world [11]. Despite the fact that savannas cover a greater area of the earth's surface than tropical moist forests, the latter areas receive more attention in the western media and research traditions, a situation that must be rectified [14-16]. Savanna landscapes vary in the relative proportions of trees, shrubs and grasses, and such variability is due to both human and natural elements [17,18]. There is a broad range of climatic types within which savanna may develop, with average annual rainfall varying from 2000 to 250 millimeters, these being intermediate between moist forest and desert [6,19,20].

## Theoretical Developments

The study of the paradigms that have been developed to describe and analyze the complex relationships embedded in savanna ecology and phytogeographical dynamics at the savanna/forest boundary is "an immense subject" [21]. The theoretical paradoxes and controversies that have been generated by such conflicts within the multidisciplinary literature on savanna vegetation have been amplified by the multiplicity of contexts and compositional forms that characterize this biome [16-17]. Nevertheless, further attempts to understand these contexts are worthwhile, because "the majority of people in the tropics, over one-fifth of the world's population, live in savannas" and such studies may contribute to "the long term survival of so many people, who are already threatened with landscape degradation, drought, famine and disease" [19]. Ecological theories must be adapted to explain and analyze contexts that exhibit the co-dominance of grasses and trees, and the socio-environmental dynamics that influence such ratios [22,23]. An intriguing possibility for the critical mind is the creation, through research, of incisive knowledge on and around perceived theoretical gaps and inconsistencies, the better to explain at various spatial scales, environmental change [19,24-26]. Useful tools in such endeavors are ground ecological surveys, aerial photographs, maps and satellite imagery [14,19,20,27-30]. Because of these complexities, it has become an intriguing question to construct theoretical models to describe, analyze and possibly enable the management of savanna contexts [31-33]. This is of "intrinsic, heuristic value", but a balance must be struck between general models and contextual variations [9, 34]. To test these models there must also be field studies [15,19,35]. The complexity and heterogeneity of savanna vegetation has created several theoretical controversies, largely due to the prevalence and dominance of structured paradigms that are insufficiently sensitive to context and value perceptions [11]. A key issue concerns the tendency to see all savannas as the products of forest modification and degradation, although their complexity and spatial prevalence in variable climatic contexts merits an examination of their uniqueness from a broader and more objective perspective. It must be recognized that "the 'core' savannas are ecosystems in their own right..." not "simply secondary forms derived from forest communities", and there is need for research into their "peculiar ecologies and ethno ecologies" [19, 36].

This is an important point, as there is a "common misconception is that savannas are transitional between grasslands and forests" [11], even though pure grasslands are rare in, for example, Africa and trees and shrubs commonly exist in dynamic disequilibrium with grasses. There is also a difficulty in distinguishing "tree" savanna from "shrub" savanna, as there is no clear distinction between trees and shrubs.

Trees may be defined as plants with a distinct bole or trunk exceeding seven to eight meters in height, while shrubs may be shorter, low branched with short, "contorted" stems, although such distinctions may be "unrealistic", as under varying conditions, tree/shrub definitions

may overlap [11]. An important point in that does not mention is the role played by firewood cutting in the creation of low stemmed and branched trees that pass for shrubs: a good example being the 'stunted' neem trees (*Azadirachta indica*) that dominate certain 'thicket' contexts of the coastal savanna of Ghana [22, 29].

The abiotic factors are also open to misinterpretation [15, 37]. In terms of fire occurrence for example, fire can be taken to be a natural aspect of the dynamism of the ecosystem rather than an unusual occurrence that converts forest into grassland [38]. Therefore, the "association between fire and savannas is as old as savannas themselves, since it follows from their climate and fuel characteristics" and to "argue from this observation that savannas are merely arrested forests is analogous to saying that if they received more water they would be forests" [11].

The positing of "ethno-ecologies" [19] as a vital area for research inquiry highlights the key role played by social dynamics in the promotion of environmental disequilibrium and complexity. Supporting authors, all of whom argued for holism rather than reductionism for further socio-environmental understanding [37-44]. This is also relevant to the position that paradigmatic and cultural perspectives, within larger knowledge systems, have created polarized viewpoints on environmental phenomena. Several authors [16,19,37,43-48] offer the example of fire, which may be viewed as a negative factor from the forest ecology perspective (because it causes deforestation), yet positively by those who study savannas (especially savanna ecologists) and the farmers, herders and other rural actors whose livelihoods are enabled by centuries of adaptation to savanna contexts.

The conclusions to be drawn from this ecological debate reflect recent developments in ecological and possibly sociological research, in particular the dynamic structuration perspective in the social sciences [49, 50] which rejects the deterministic linearity of social structural analysis. Here, complex social action is related to ecological change, in a dynamic relationship, resulting in continual savanna change. In the context of socio-environmental relations in the African savanna, such approaches view cultures as being in constant, largely non-linear transition, both in terms of their co evolutionary relationships with the environment [51-53] and with regard to the flexible fabric of society, emphasizing the dynamics of social action within a constraining and enabling relationship. The intrusion of disequilibrium theory into the social sciences has spawned new topics and sub-disciplines [38], examples being co evolution [54, 55] political ecology [56-63] human ecology [64] cultural ecology [65-66] the cultural ecology of development [67] and environmental sociology [44].

## Hierarchy Theory and the PAM/PAN Plane

Analyzing the basic issues around which further theoretical discourse may be developed, it is argued that "savanna form is governed by the intricate interplay of five key ecological factors, namely Plant Available Moisture (PAM), Plant Available Nutrients (PAN), fire, herbivore and major anthropogenic events" [19]. These may be also expressed water, nutrients, fire, herbivore and human activities [11]. These are a "hierarchy of determinants" because it is possible to place these factors in a hierarchy in terms of significance and causative linkages. One argument is that PAM and PAN are the "initial determinants" with fire, herbivore and anthropogenic influences being classified as "secondary modifiers" of the primary production resulting from PAM and PAN [19].

This perspective in ecological theory led to the postulation of

the 'PAM/PAN' plane which assumed that PAM and PAN were key determinants, and hence, the properties of savanna systems "be located within a plane defined by axes of PAM and PAN", with location specific variations being used for classifying savannas [19]. Experience suggests a contrary view: PAM and PAN are not equal, "PAN is nearly always constrained by PAM" and in many instances PAN exercises no significant control at all, so that "PAN is thus lower in the hierarchy of determinants than PAM" [19]. The importance of moisture as a contributory factor has been strongly supported in the literature [2,9, 21,34,35,68].

Other authors modeling savanna dynamics differ in the relative importance they attach to the hierarchy of fire, herbivore and historical, anthropogenic factors Werner PA et al. [9,22,34,68] places human influence at the third level of the hierarchy, equal with fire and herbivores, but [19] produces a model that place such issues at the top of the hierarchy. Each of the factors at the different levels of the hierarchy is termed as 'holons' or subsystems that interact with other subsystems at the same level of the hierarchy. Holons also affect those lower down in the hierarchy. Therefore, if human factors are placed at the top, it means that people affect fire and herbivory, which also affect PAM and PAN. PAM may be ranked above PAN because moisture (from rainfall, ground water and even irrigation) affects nutrients more than the other way around.

The application of this hierarchical model to spatial ecological analysis follows the "four basic scales" of savanna studies (progressively from small to larger, these are patch, catena, landscape and region) [16,19,29]. In small areas species composition is more important, while at the landscape level it is broad vegetation physiognomy. Human influences and PAM (largely affected by climate) are important at all levels (patch, catena, landscape and regional) while fire and herbivory are more relevant to the first three, because of contextual variation over regional scales. PAN, by contrast, is more relevant at the patch and catena spatial contexts, as soils vary greatly at such levels. Holons or subsystems may be further deconstructed into a more detailed hierarchical analysis. For example, PAM is variable at the catena level, in terms of ground water and topographical factors, evapotranspiration and infiltration rates. These variables must be contextualized at different spatial scales, and the perception of such scale linkages will be helpful in understanding environmental change [19, 39]. While the approach is useful, the research foci of individual researchers may hamper its applicability. The emphases of some biologists at the patch scale constrains the development of research at larger spatial scales [19, 69]. Subjectivity of appraisal is an overall problem, as each investigator stresses the variables that are of individual interest [70].

An example concerns the difference between the perspectives of ecologists and biogeographers [70-79]. The emphases of ecology are largely micro scale issues such as plant reproduction [77] plant/animal relationships [76] competition between organisms [64], plant structure and function [78] and ecosystem functional interactions [78]. Many biogeographical studies [71-79] emphasize the broader issues of floral history [72], vegetation structure and form [73], plant diversity and endemism [72] and time regimes [75].

Over-generalizations, subjective definitions of scale and insufficiently detailed research are also serious problems. This is partly due to the lack of empirical data from censuses over the long term [15,16,37, 68,80-82]. Studies at all the scales will be necessary before the linkages in the hierarchy of determinants can be used to analyze environmental change, examining processes that influence phytogeographical form upwards from the patch to the global scale and down again.

## The Equilibrium/Disequilibrium Debate and the African Savanna

The relationship between forest and savanna vegetation, and the determination of the extent to which one vegetation form has replaced the other is a contested issue in the literature. The cited references [2,3,14,19,24] are very relevant because the extent to which forest and savanna vegetation replace each other, and the relative roles of human factors, fire (natural and human induced), herbivores, plant available moisture (or PAM, usually expressed as rainfall, ground water and sometimes, relative humidity) and Plant Available Nutrients (PAN) are given varying prominence [83]. Note that there is not even consensus on the actual extent of annual global deforestation: estimates vary from 33,000 to 201,000 km<sup>2</sup>.

Some models offer strong predictions of global biodiversity change, without considering the possibility of unpredictable events [37,84,85]. This may result in flawed perceptions of environmental change. For example, dry season severity is a principal factor influencing the development of savanna vegetation, and this may be complemented by farming, fires and edaphic factors to reduce the density and extent of tree stands [15,18, 21]. The actual effects of farming, firewood cutting, timber extraction and construction on the environment are disputed [86]. Argues that the environmental impacts of socio-environmental relations depend on the "specific historical and geographic conditions which obtain in a given situation". Yet, arguments concerning the factors involved in the relationships between savannas and forests (and sometimes deserts) have become underlying cores of general and polarized theoretical perspectives.

A fundamental dispute within savanna ecology concerns the rise of paradigms that emphasize non-linear disequilibrium models (this paradigm may also be termed the "new ecology" [38] as counterpoints to the classical position of linear, mechanistic change exemplified by 'natural' vegetation [87], climatic climaxes, succession and human-nature separation [2,15,37,88]. The equilibrium position favored ecosystem theory, mechanistic succession and vegetation climaxes, because there was an inherent assumption in the power of generalization and scientific universalism [44,80,82,89-94,]

The "non equilibrium hypothesis" has developed slowly over the years [2, 95- 96, 97, 98]. These positions may be termed disequilibrium analyses, because they emphasize the dynamics of interrelationships within complex and unpredictable socio- environmental contexts [11, 14,24,88,99]. "Chaotic fluctuations" in socio-environmental contexts are emphasized [38], challenging the equilibrium position of classical ecology (as argued for example by [94,100-101]).

One example is are the studies of savanna soils in Zimbabwe, where "the way environmental change is conceptualized is crucial", and suggests a need for further studies that emphasize "non-linear, multi-directional, punctuated... dynamic and non-equilibrium possibilities for processes of transformation", and an understanding of ecosystem change "in more historical terms" [ 37 ]. Field work is thus important. Intrinsic in this approach is the recognition that changed environments "do not necessarily revert to their previous state when the occurrence of the disturbance ceases [2, 35, 38, 68]. To this may be added the caution that the previous state may not be known. It is thus necessary to investigate the "site histories" of particular contexts [38]. The incorporation of social dynamics will complement this, enhancing a perspective that sees the environment as influencing and being influenced by people [37,52,85,88] and often subject to "multiple interpretations" and "various forms of uncertainty and indeterminacy" [37].

The opposing equilibrium paradigm for biosphere phenomena is “hindered by a number of formidable difficulties”, a problem which is due to the “large number of variables and poorly known parameters blurring some fundamental underlying regularities” [ 102 ]. It is also fundamentally flawed, because “it overlooks the possibility that both the biota and our physical environment are dynamic systems generating complexity as a result of the very nature of the laws to which they are subjected”. A further problem occurs because knowledge derived from certain contexts, such as the temperate grasslands or tropical forests, is not adequate for the explanation of the dynamics of savanna change, which may include “bush encroachment and multispecies herbivory” [11] necessitating a broad perspective [16,103].

Descriptions of forest/savanna boundaries as lines are often oversimplifications. Such complex disequilibrium or “bifurcation and chaos” of the “geosphere- biosphere system is, to a large extent, an intrinsic property, rather than a manifestation of incomplete knowledge or of the presence of a large number of variables and parameters” [68]. Crucially, “unpredictable abiotic events” are part of “healthy ecosystem behavior” [15].

The fundamental characterization of natural (and sometimes socio-environmental) systems within the equilibrium paradigm is that of linearity, end points and nature/society separation [21,36,85,98] and biogeographical generalization of biomes [105]. Examples are ‘cause and effect’ perspectives, sequential change and mechanistic succession, end states or climaxes. With predictable progress within an ecosystem being charted by scientific investigation, new and little understood ‘interruptions’ such as environmental catastrophes or human ‘intervention’ are posited as anomalous externalities which temporarily induce disequilibrium, a situation which time corrects as the system slowly recovers its previous equilibrium, or which may permanently degrade it. This perspective, related to Newtonian physics, propounded the notion of “deterministic dynamics” and the essence of as “a few simple laws” Sullivan S et al. [15,106] criticizes this paradigm, and points out that “the crucial point about thermodynamic systems is that any deflection from normal behavior or equilibrium is seen as a random fluctuation or noise rather than as an integral part of the system”.

The view of the natural system being in equilibrium is not limited to the ‘scientific’ community, but is prevalent in political and wider public circles, leading to linear models of development [15,37,107] which may be described as the Dominant Development Paradigm. There is evidence that “until recently, for the public and the vast majority of scientists themselves, the world was viewed as a harmonious system that was in a state of equilibrium or near it” [106]. Common themes for this perception were the “balance of nature”, an “ideal state of nature” and nature’s “proper functioning”. The institutionalization of this paradigm within scientific, and even economic, circles served to legitimize scientific and socio- economic models, both nationally and globally [15]. The term “balance of nature” was described as a “cultural metaphor” which is “rooted in western culture” [ 88]. Within development policy it is “still very much alive and well in some quarters” and is related to an “objectivist” approach to environmental problems [44].

## Case Studies of the African Savanna

Relating these issues to the African savanna, several studies have revealed conflicts between established, ‘institutionalized’ views of environmental ‘degradation’ and the evidence revealed in satellite imagery, aerial photographs and/or field research. This has been reflected in new surveys, which reveal that African savanna landscapes

are “non equilibrium or multistate systems which tend to flow from one state to another” and that the advance of deserts does not follow the simplistic sequence frequently portrayed in the literature [2,35]. Thus, a key issue for theory concerns the prevalence of equilibrium and linear thinking as established doctrine and the discovery of new evidence postulating a disequilibrium perspective [11].

More recent studies of African environments that test these hypotheses tend to utilize four main sets of data: aerial photographs and/or satellite imagery, ground surveys, social research and historical data. In particular, aerial photographs are favored because they give a more objective indication of change than policy discourses or ground surveys of different times [51,52] Examples of such studies are discussed below.

The findings of a study conducted in Namibia suggest that the extensive, environmental catastrophes enumerated in many studies do not exist, and such opinions are based on personal beliefs “rather than on the weight of empirically tested evidence” [ 15 ]. These results illustrate the position that “belief in equilibrium theory amounts to verification of a paradigm due to faith in that paradigm” [97]. In Namibia, established ‘wisdom’ perceived the environment as a human constructed disaster. Vegetation was devastated by overgrazing [108], there were extensive counter effects on the livestock industry [109] and an eventual “collapse” was envisaged Sullivan S et al. [15,110] study showed contrary evidence: climatic variability allowed grassland regeneration, questioning both the negative assessments previously established and also the validity In another study in Guinea, [51] there was evidence of a “vegetation history that sharply contradicts the deforestation analysis and thus exposes the assumptions in its supporting social narrative; assumptions stabilized within regional narratives based more on western imagination than African realities”. The environmental context examined in this case was the forest margin zone in Guinea. Embedded in this study are refutations of the position that local communities have declined in their ability to maintain forest vegetation and other environmental resources, and that a forested past was thus analogous with a “moral” past. The “deforestation narrative” is a powerful treatise on how structural, socio-economic change is believed to have contributed to deforestation and how this has caused socio- environmental externalities. The “counter narrative” explores aerial photographs which provide “incontrovertible evidence” of increased or stable forest areas between 1952 and 1994. The data are supported by the testimony of local respondents, colonial records and oral history.

This study on Guinea refuted many issues of the established narratives, and supported the disequilibrium perspective in phytogeographical change [51]. In this study, in some contexts, “local land use can be vegetation enriching as well as degrading” and it “can (and often does) serve to increase the proportion of useful vegetation forms and species in the landscape, according to prevailing local values and productivity criteria” [51]. This may be exemplified by maintenance or actual increases in tree stands through planting of “forest initiating trees” (“forest islands” may expand around villages), enrichment of soil through dumping of household waste and gardening, the cutting of flammable grasses, and seed source protection [51-52].

The dynamism of socio-environmental relationships, within the larger issue of savanna disequilibrium, was also revealed to be based on the sum of a “diffuse set of relations, a constellation rather than a structure”, relegating to secondary importance the overly structuralist perspective emphasizing sociocultural organizations and village leaders [51]. There was evidence of complex interactions at individual actor,

household, and compound levels (managing hunting and farming fires which prevent larger fires later, and the planting of tree crop plantations) within integrated relationships, that “the combined effect on resource enrichment is greater than the sum of their parts” influencing the form of phytogeographical disequilibrium. This points to a structuration perspective, as although these activities are decided at the actor level, through the larger structures reinforced by local people, village leaders do exert a certain amount of influence over burning, cattle tethering dates, the co-ordination of rotations and negotiation with pastoralist settlers.

The relationship between deforestation and population increase, frequently portrayed as linear and positively correlated, was also revealed to be dynamic, complex and in some cases negatively correlated. In the Ziama area of Guinea, populations have not increased, as commonly believed, while new research challenges the deforestation narrative which holds that the forests of Ziama are relics of larger stands, degraded under population pressure and socio-economic change, revealing forest expansion [51].

The assumption that there was original “African vegetation” that fell within a definite climax which, under unchanging conditions, was subjected to degrading human activities was not substantiated in this study. Also refuted was the belief that traditional “African society” was in the past “harmoniously integrated with ‘natural’ vegetation”, and was “sedentary and subsistence oriented with an anti-commercial sentiment”, a situation that is believed to have changed with socio-economic structural change, described with temporal and linear analysis [51].

In terms of practical application, the disequilibrium counter narrative may have the potential to develop and contribute to “different and more appropriate guidelines for policy” [51]. This approach exhibits greater sensitivity to local issues and dialogues with actors conducted in a participatory and horizontal, rather than vertical framework and rejects the existence of a “baseline link between society and vegetation form”, a position that has justified corrective development interventions to rectify deviations from a “lost social order” [51].

In another study in the Machakos Reserve of Kenya land degradation, termed the “Machakos problem” was believed to be caused by “environmental misuse” population growth, the expansion of dry land farming and livestock rearing, with resultant famine and forest to badland trajectory [112]. Examination of photographic evidence from 1937 and 1991, however, shows the opposite: badlands have been replaced by farmlands, “erosion scars” have been reduced or have vanished, tree numbers have increased, the vegetation on grazing lands is virtually unchanged, and all this has taken place in the face of a fivefold population increase in the area between 1937 and 1991. Even technology appeared to be developed and made more effective by population growth that broadened socio-environmental relations. Increased population meant increased food needs, labor supply, idea creation and development of infrastructure. People struggled successfully with the environment for sustenance [112,114].

The merit of these case studies [15,51,52,112,113,115] stems largely from their contribution to the argument that it is parochial to take a mechanistic viewpoint on socio-environmental analysis. However, while these studies happened to be in areas where evidence from aerial photographs and local surveys contradicted established discourse on deforestation, this does not mean that there is no deforestation in Africa. Some studies [51,52,115] too often generalize about their findings by using the term “West African” or “African” as if different

contexts all support the same counter narrative. The innumerable contexts of the African continent offer ample scope for different forms of phytogeographical change, including sequential deforestation. It must be noted that “the pendulum can swing too far in debunking orthodoxy” [85]. Therefore, it is necessary to take a final reflexive look at the results, thus not to over generalize the counter narrative [51,52,115].

For example, in the Guinea savanna of the Upper West region of Ghana [116], similar research tools as those in the cited references were used [51,52,115] (Land Satellite Multi-Spectral Scanner (MSS) images from 1972 and 1989, local ground surveys, and semi-structured interviews), but the conclusion showed not reforestation, but deforestation, with the most significant changes being around the settlements of Busie, Wa and Han, where grain cultivation and animal rearing were intensive. Therefore, the deforestation narrative was found to accurate, with generalized substantial tree losses, and only limited regeneration in local areas.

In another study in the coastal savanna of Ghana [117] used aerial photographs, quadrats, social surveys and archival data, and also found deforestation. The Pinkwae area of the coastal savanna of Ghana also contains fetish groves however, which comprise 1.2 square kilometers of forest. This was the site of a battle between the people of Katamanso and the Ashantis in 1826. It is believed that the spirits of the ancestors who died in the battle live in the fetish groves with the god Afiye, the deity who was believed to have helped rout the Ashantis. Thus, within the fetish grove, no farming is practiced and trees prosper. However, outside the fetish groves, farmland has replaced tree stands [117-118].

In a study utilizing remotely sensed data and field data collection covering eight countries (Ghana, Congo, Cote de Ivoire, Ethiopia, Mali, Senegal, South Africa and Zaire), the results showed substantial deforestation had occurred in several areas, with cases of drier savanna woodland showing signs of ‘severe degradation’, being replaced by farm/shrub/grass mosaics. Farming and firewood cutting were blamed for the substantial tree losses, but the boundaries of the forests and savannas were argued to be dynamic, due to the unpredictable human and climatic influences [18]. Another study utilized remote sensing, which revealed tree losses in the savanna woodland of Guinea, Sierra Leone and Cote de Ivoire. By the “end of the dry season, however, a more or less continuous burned belt 100-200 kilometers wide is found in the southern part of the savanna range” [1].

A study in the Highlands of Tigray in Ethiopia using remote sensing also found substantial vegetation losses, which was posited as the factor behind increased soil erosion [119]. Another study in the hinterland of Niger [111] used satellite imagery and found deforestation over a period of twenty years, largely as a result of population increase, over exploitation of cropland and overgrazing of rangelands, causing pronounced erosion. In the Cross River area of Nigeria, a similar result was found [112] Based on maps, aerial photographs, Rapid Rural Appraisal, questionnaires, archival and documentary sources and informal interviews) the study revealed substantial deforestation. In this study, farming is posited as the main factor behind declining tree stands.

Nevertheless, such contrasting research results do not negate the disequilibrium analysis, but rather strengthen it. Evidence from aerial photographs may arguably represent “incontrovertible evidence”) of different forms of (general) phytogeographical change, viewed from the vantage point of wider processes of socio- environmental interaction [51]. This underscores the dynamic and heterogeneous nature of the

West African savanna. Further, neither deforestation nor reforestation represent permanent trajectories, but may be subject to change over time [37]. Therefore, the strength of the disequilibrium position rests in its ability to survive different research conclusions, because these variations are further evidence of disequilibrium and heterogeneity [15,38].

The foregoing debates concerning ecological change thus tend to refute the notions of linear succession towards a single vegetation climax. What they seem to suggest is a scenario of more or less permanent multi-directional transition provoked by complex sets of variables “rather than by trends in (a) particular variable (s)” [51]. Such change may be divergent, as the removal of a factor of disturbance may not return a formation to resembling its original form [2,15,66,120]. Thus, the contingent nature of vegetation form may make investigation of a region’s “archetypal vegetation” redundant [51].

## Conclusions

This article has examined the main theoretical arguments and ecological methods that have been developed to analyze the structure of the African savanna, contrasting the more recent disequilibrium ecology paradigm, which sees the savanna as in continual flux rather than stable equilibrium, with the older equilibrium paradigm, and examined the relations with the social sciences and the evidence for these paradigms. The results hint that the complexity of the African savanna justifies the integrated research methods, which provide a useful basis for the advancement of biodiversity studies. The citations in this article are not intended to give an exhaustive list of problems and solutions, but for illustrative possibilities, potential new monitoring techniques, and expansion of current methods. Arguably, the multiplicity of theoretical studies that have emerged to enable such syntheses testifies to the difficulty of the construction of adequate integrative studies. Critical experimentation using the methods described utilize (aerial photographs and/or satellite imagery, ground surveys, social research and historical data). appears to have high potential and these may provide a good testing ground, with possibilities for generic application elsewhere. If such integrated research is to be truly effective in the more accurate assessment of savanna status and change, measurable parameters must be identified, within the multiple strands of ecological and social relations, in multiple real or hypothesized scenarios, with multiple techniques, including images, statistics, qualitative social measurements and frameworks of integration.

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