CENTER FOR INSTITUTIONAL REFORM AND THE INFORMAL SECTOR

University of Maryland at College Park

Center Office: IRIS Center, 2105 Morrill Hall, College Park, MD 20742
Telephone (301) 405-3110 • Fax (301) 405-3020

THE LOCAL VARIABILITY OF RAINFALL AND TRIBAL INSTITUTIONS: THE CASE OF SUDAN

June, 1995

Jeffrey B. Nugent and Nicholas Sanchez

Working Paper No. 168

This publication was made possible through support provided by the U.S. Agency for International Development, under Cooperative Agreement No. DHR-0015-A-00-0031-00 to the Center on Institutional Reform and the Informal Sector (IRIS) and administered by the Office of Economic and Institutional Reform, Center for Economic Growth, Bureau for Global Programs, Field Support and Research.

Authors: Jeffrey B. Nugent, University of Southern California, Los Angeles, CA.
Nicholas Sanchez, Department of Economics, College of the Holy Cross, Worchester, MA.

THE LOCAL VARIABILITY OF RAINFALL AND TRIBAL INSTITUTIONS: THE CASE OF SUDAN*

Jeffrey B. Nugent and Nicolas Sanchez**

University of Southern California and College of the Holy Cross

May 1995

* An earlier version of the paper was presented to the Session entitled "Political Economy and Institutions of the Middle East" of the Middle East Economic Association/ASSA Meeting in Washington D.C. on January 7, 1995

** Jeffrey Nugent expresses his appreciation for financial support of the underlying research to the U.S. Agency for International Development under Cooperative Agreement No. DHR-0015-A-00-0031-00 to the Center on Institutional Reform and the Informal Sector (IRIS) and administered by the Office of Economic and Institutional Reform, Center for Economic Growth, Bureau for Global Programs, Field Support and Research at the University of Maryland. Both authors thank Professor Mike Hulme and the Climatic Research Unit, School of Environmental Sciences, University of East Anglia, for making available the historical rainfall data from 168 weather stations in Sudan and thank Sami Khedhiri, Victor Gastanaga and Seung-Jae Yhee for their able research assistance in collecting and manipulating the complementary data. Finally, the authors thank Ali Kutan and Ragui Assaad and other participants at the MEEA/ASSA meetings and seminar participants at USC and California State University, Fullerton for their useful comments on the earlier version of the paper.

THE LOCAL VARIABILITY OF RAINFALL AND TRIBAL INSTITUTIONS: THE CASE OF SUDAN

This paper develops and tests hypotheses relating rainfall variability to two aspects of tribal institutions: the degree of commonality in property rights and the degree of centralization or hierarchy. In contrast to most existing studies which deal with intertemporal variability of rainfall in a given area, this study focuses on the effects of the local (spatial) variability of rainfall. When risk-averse agents attempt to maximize their utility in the face of production and price risks arising from local as well as intertemporal variability of rainfall, it is shown that their welfare can be enhanced by a tribal institution which pools the land parcels of all members of the tribal society in such a way as to allow every member access to every land parcel. It is also argued that local variability should lower the degree of centralization or hierarchy in the tribe, both directly and indirectly.

Historical data from ethnographic studies on a cross-section of 41 Sudanese tribes and meteorological data from 168 rainfall stations are combined to generate indices of relevant variables and indicators. The resulting indices are then used to test the hypotheses developed in the paper. The results provide at least tentative evidence in support of the hypotheses. In particular, the following hypothese are supported: (1) The degree of openness of tribal land to all members of the tribe is positively related to the degree of local variability of rainfall but negatively related to mean rainfall. (2) The relative importance of agriculture vis-a-vis animal husbandry is positively related to mean rainfall, but negatively related to the local variability of rainfall. (3) The exogenous component of the choice of agriculture (has a significant negative influence on the degree of openness but an insignificant influence on the degree of centralization or hierarchy of the tribe. (4) A greater degree of centralization is needed when both agriculture and animal husbandry are practiced in relatively close proximty in the environmental conditions of ASARs. (5) The degree of centralization or hierarchy is also found to be negatively related to the degree of openness and also both directly and indirectly to the local variability or rainfall. (6) Although not devoid of methodological problems, and based on only a small number of sample observations, there is also some tentative evidence of a significantly positive relationshuip between the degree of openness and efficiency in the production of animal husbandry.

One important implication of the analysis is therefore that local variability of rainfall is characteristic of ASARs in tropical countries. Another is that where this characteristic is rather pronounced, it suggests an

important qualification of the validity of the usual policy prescription in favor of private property rights and individually managed and operated farms.

THE LOCAL VARIABILITY OF RAINFALL AND TRIBAL INSTITUTIONS: THE CASE OF SUDAN

ABSTRACT

The purpose of this paper is to develop and test hypotheses relating rainfall variability to two aspects of tribal institutions: property rights and the degree of centralization or hierarchy. In contrast to most existing studies which deal with intertemporal variability of rainfall in a given area, this study focuses on the effects of the local (spatial) variability of rainfall. When risk-averse agents attempt to maximize their utility in the face of production and price risks arising from local as well as intertemporal variability of rainfall, it is shown that their welfare can be enhanced by a tribal institution which pools the land parcels of all members of the tribal society in such a way as to allow every member access to every land parcel. It is also argued that local variability should lower the degree of centralization or hierarchy in the tribe, both directly and indirectly.

Historical data on a cross-section of 41 Sudanese tribes and meteorological data from 168 rainfall stations are combined to generate indices of relevant variables and indicators. The resulting indices are then used to test the hypotheses developed in the paper. The results provide at least tentative evidence in support of most of the hypotheses.

In recent years economists have been making considerable progress in explaining institutional arrangements, and especially in relating variations in environmental conditions to variations in the character of rural institutions.[1] Nevertheless, with respect to explaining property rights and the structure of indigenous societies, economic explanations have generally remained extremely overly simplistic,[2] thereby leaving much of the explanation to political scientists, sociologists and anthropologists.[3]

The purpose of the present paper is to extend conventional economic explanations for the choice of property rights and the type of social structure (which typically include the scarcity value of land) so as to include also the spatial variability of environmental factors. While numerous other environmental characteristics may also be subject to considerable local variability, because of its general importance and measurability the focus of this paper is on the local variability of rainfall. The model is used to derive testable hypotheses concerning the degree of private property rights, and the degree of centralization or hierarchy in social organization. Finally, it uses data from different parts of the Sudan to provide evidence on the validity of the hypotheses.

The paper is organized as follows. Section I provides the rationale both for the focus on the local variability of environmental factors, including possible explanations for its virtual neglect in the existing literature, and for the choice of different tribal areas in Sudan as the locale for the empirical application. Section II develops the theoretical model and derives the relevant

---

1 For example, Hans Binswanger and his collaborators [Binswanger and Rosenzweig (1986) and Binswanger, McIntire and Udry (1989)] demonstrate how the degree of aridity is likely to affect the relative importance of risk, the choice of technology and the degree of development of land, credit and labor markets. Note also the rapidly increasing literature attempting to explain the interlinking of markets and contracts and the choices among various-kinds of contracts [e.g., Bardhan (1989), Nabli and Nugent (1989), Hayami and Otsuka (1993) and Lin and Nugent (1994)].

2 In particular, the extent of private property rights in land is said to be affected primarily by the scarcity value of that land and the costs of exclusion. Thus, a higher scarcity value of land relative to the cost of exclusion of others from use is said to increase the likelihood of private property rights.

3 This is most obvious with respect to the explanation of the degree of social hierarchy or political concentration among different social groups such as tribes, where (as far as we are aware) the explanations are entirely political and cultural.

hypotheses concerning property rights in land and the degree of hierarchy. Section III describes how measures of the relevant variables were constructed, identifies the data sources and presents the data used in the empirical tests. Section IV presents the empirical results and Section V our conclusions and suggestions for further research.

I. Local Variability of Rainfall and the Sudan

While variations in weather in general and rainfall in particular have been widely recognized as important sources of production and price risk, the aspects which have received almost all the attention have been intertemporal changes within a given location or region. Among the important questions of this sort which have been raised and for which answers have been sought are: (1) Are the geographic areas in which droughts have been most prominent, such as Africa's Sahel, becoming drier over time? (2) Are the rainfall patterns of the last twenty years different from those of the preceding decades and centuries? (3) Is global warming taking place? (4) If the answers to any of the above are affirmative, what are the causes and effects of each of these changes?

Virtually neglected, however, have been the local (spatial) variability of such environmental faotoro and hence such questions as: (1) To what extent do the risks to rural production and incomes arising from insect infestation, plant and animal diseases, fire, drought, and floods vary from one local community to another? (2) How important are these variations? (3) If they are important, what do the individuals and groups living in such areas do about these locally varying sources of.such risk?

Several factors would seem to contribute to the neglect of such issues. One is that, in the temperate and relatively humid zones of the world where a majority of the world's population live, such local variability of temperature and rainfall (the latter usually measured by the steepness of the decline in the correlation coefficients in daily or monthly rainfall with distance between rainfall stations) is relatively small.[4] Another is the comparative dearth of data from a

4 For example, aee Stol (1972) for the Netherlands, Huff and Shipp (1968), Huff (1970) and Jackson (1988) for Illinois in the U.S., Johnson and Dart (1982) for the Pacific Northwest of the U.S., Hutchison (1970) for New Zealand, Anderson (1970) for Southern Queensland and New South Wales in Australia, and McConkey, Nioholaichuk and Cutforth (1990) for Saskatchewan in Canada.

multiplicity of weather stations in a given region.[5] Still another is that intertemporal variations would seem to be more amenable to policy treatment than interregional ones. Also, since the local instability of rainfall is almost invariably much lower for annual than for (the frequently more relevant) daily or monthly observations, the fact that so much of the published data from which such correlations can be computed is annual greatly understates the magnitude of these local instabilities. Finally and perhaps most importantly, whereas in relatively humid areas where agriculture is practiced, because drought-induced production shortfalls are generally associated with price increases, price risk tends to offset production risk, thereby lowering the overall importance of weather-related risks for farmer incomes.

Yet, there is growing evidence from various arid and semi-arid regions of the world suggesting that the local variability of rainfall is considerably greater than in the more temperate and humid areas of the world. For example, Sharon (1972, 1979) showed that the coefficients of correlation in the daily rainfall amounts recorded at different pairs of rainfall stations in Southern Israel and Jordan fell from 0.9 at a distance of 2 kilometers to 0.6 at a distance of 5 kilometers, and 0.25 at a distance of 25 kilometers. Similarly for Tanzania, Sharon (1974) and Jackson (1988) showed that correlation coefficients in both daily and monthly rainfall among pairs of rainfall stations declined rather sharply with distance. Sharon (1981) showed these correlations in rainfall amounts of given distance to be especially low in the desert areas of Namibia. Also, Giovinetto (1972, 1974), Monteverdi (1978), and Cladipo (1987) have demonstrated that the local variability of rainfall between stations of a given distance tend to rise as one moves southward within the Great Plains of the U.S. and from cold climates in both the Northern and Southern hemispheres into warmer and more arid ones regions such as the American Southwest.[6] Finally, Thompson and Wilson (1994)

---

5 For example, with respect to the relatively arid areas of Africa and Western Asia, Hulme (1992 and via private correspondence) reports that none of the following oountrico has as many as a dozen weather stations with a significant number of simultaneous observations on monthly rainfall: Morocco, Algeria, Tunisia, Libya, Egypt, Ethiopia, Somalia, Angola, Namibia, Chad, Botswana, Mauritania, Burkina Faso, Niger, Mali, Jordan, Syria, Iraq, Kuwait, Saudi Arabia, Yemen, Oman, United Arab Emirates, Qatar, Iran, and Afghanistan.

6 Similarly, Sanchez and Nugent (1993) showed the correlation coefficients for both monthly and daily rainfall observations from pairs of rainfall stations of given distance to be significantly lower in relatively humid Iowa than in relatively dry Wyoming and Western Texas.

report various studies showing somewhat similar patterns in the arid and semi-arid regions of Northern Mexico.

Moreover, in the more arid regions where rainfall is insufficient for agricultural activities to be feasible and hence where only animal husbandry is viable, price changes are not likely to offset production changes. Indeed, in drought conditions, animal herders are generally forced to sell off their animals at low and falling prices (distress sales) implying that production and price risk are likely to compound each other rather than offset each other as in the case of agriculture. Hence, income risk is bound to be considerably more important in more arid than in less arid regions. Such risks are also magnified by the fact that herders' incomes are likely to remain low longer in droughts than those of farmers because of the fact that herder incomes are highly contingent on the size of existing herds which are far less able to spring back from droughts than those of agriculturalists.7

The aforementioned greater relative importance of local variability in rainfall in more arid regions and especially in the more tropical ones can be attributed to a number of different natural factors. First, tropical rainstorms are generally more unstable, less predictable and of shorter duration than those in more temperate regions. Second, the diameter sizes of the rain-producing clouds in tropical and arid regions are generally considerably smaller than those in more temperate and humid regions. Third, the evaporation of the pools formed after such rains is generally much more rapid in dry tropical areas. Fourth, the fact that the Sahel and other arid and semi-arid regions of Africa, the Middle East and the American Southwest are notable for having mountains' interspersed throughout the plains makes for stronger convection in both air currents and rain storms, again lowering the correlation in daily and monthly rainfall between nearby areas.

The emphasis in this paper on rainfall is dictated not only by the fact that rural incomes are far more dependent on rainfall than on other sources of production and price risk but also by the fact that rainfall statistics are far more available than those on insect and plant and animal disease infestations and flooding.

7 These considerations no doubt contribute substantially to the explanation of the findings of Sen (1981) and others which show that herders show up prominently as the most frequent and severe victims of famines.

Our choice of Sudan as the country for relating the local variability of rainfall to property rights and social structure is based on several considerations. First, Sudan is the largest single country in Africa and, as a result, has exceptionally great variation in rainfall amounts and variability from one region to another. In particular, its southern part is generally subject to fairly high levels and low variability of rainfall while (with some exceptions) its northern, eastern and western parts have much lower levels of rainfall but higher variability, both spatially and intertemporally.

Second, because of the paucity of the country's other resources, such as minerals, energy sources and educated people, and the concentration of its small manufacturing industry in the greater Khartoum area (in the center of the country) and to a lesser extent in its Red Sea ports, virtually all Sudanese living in rural areas are engaged rather exclusively in agriculture, animal husbandry[8] and to a lesser extent related trading activities.

Third, in contrast to the vast majority of other countries with substantial areas of arid and semi-arid lands, Sudan has a rather large number (168) of weather stations with simultaneous observations on monthly rainfall, and which are at least somewhat evenly spread throughout the country. Hence, it is much more possible to construct distance-standardized indicators of the local variability of rainfall for Sudan than for most other countries with substantial arid and semi-arid regions.

Fourth, it has a large number[9] of separate ethnic and cultural communities (tribes), including a relatively large number whose institutions have been described and analyzed in a surprising large number of very rich anthropological studies.[10] These studies permit the construction of at least crude indices of the degree of exclusivity in property rights and the degree of centralization or hierarchy in tribal structure. Since such studies are available for tribes from

8 With the exception of Ethiopia, Sudan has the largest number of cattle or more generally "animal units" (defined below) in Africa [Smith (1992)].

9 There are said to be over 400 tribes in the country, though many of them of rather small size and mixed composition.

10 Among the references provided at the conclusion of the present study and referred to in the Appendix are several of the many, often classic, studies that have been done on Sudan's various ethnic and tribal communities.

virtually all parts of the country as in the case of the rainfall data, they present a rather unique opportunity to relate data on the local variability of rainfall and other environmental characteristics to data on tribal and other institutional characteristics.

Finally, it should be mentioned that Sudan is very different than most countries of the region in the extent to which it has been subjected to substantial change in the distribution of land across its various ethnic and other communities and in the character of these communities. As a result of colonial policy and other influences, in most African countries their ethnic communities have been subject to frequent and very substantial changes, making it imperative to carefully limit cross-sectional (inter-tribal) comparisons to those few societies for which comparable data on the relevant characteristics are available for almost exactly the same time period (a very limiting requirement indeed as far as sample selection is concerned). Yet, the Sudanese experience has been very different in this respect, i.e., greatly limiting changes in social characteristics within the different communities and virtually ruling out changes in the locations or areas inhabited and used by the different communities.[11] An a result, Sudan's social structure and the location of its various tribal communities have been unusually static, making it more feasible to compare societies the data for which were obtained at somewhat different points in time.

---

11 Several reasons can be given for why this was so, at leastbetween the late 19th century (and in many cases considerably earlier) and the early 1970s: (1) neither previous occupations (such as the Ottomans) nor the British colonial administration made any attempt to change cither thc tribal boundarico or their institutions; (2) in contrast to other countries colonized by Great Britain, land was not alienated from the existing population in favor of colonial settlers; (3) the primary focus of British rule was to provide law and order and thereby to freeze each exioting tribal group or community within its existing tribal area ("dar"), the various dars being demarcated in maps and the policy being one allowing Great Britain to maintain its occupation of the country (thereby excluding other colonial powers) at the lowest possible administrative cost; (4) the district officers (many of whom were trained in anthropology) were appointed to the various districts of the country for relatively long periods of time so as to promote continuity in both policy and knowledge of the local tribes; (5) Sudan has experienced only very slow economic growth and social transformation; and (6) until well into the 1970s, none of the post-colonial governments had introduced any substantial changes in land use legislation or interference in tribal affairs. At most, the new legal and other institutions of the Sudanese state paralleled those of the tribes, but did not deliberately sabotage or undermine those of the tribes.

II. Theory and Behavioral Hypotheses

The economic theory of property rights has evolved only slowly from its original emphasis on the rising value of such property as the primary reason for the emergence of property rights, the rising property value brought about either by population density or a rise in the value of that which is produced by the property.[12] The more valuable the property, the *greater* the threat of rent dissipation, and hence the greater the incentive to establish property rights, either private or common.

There have been at least three major extensions of this theory over the last decade or two [Eggertsson (1990)]. One has been to recognize the role of monitoring and exclusion costs in determining the particular form which such property rights would assume, be they private or common. As Field (1985) showed, the choice between open access and common or private property need not be a discrete one but rather one of choosing a point on a continuum. For any given land area of given quality, productive technology and population (of potential users of the land (N)), the average size of the commons (S) would be N/n where n is the number of commons or subdivisions of the land, Individual private property rights exist when n=N and S=1, whereas pure common property rights exist when there is a single commons (n=1) used by the entire N, i.e., where S=N. The optimal point on such a continuum of types or property rights would be determined by equality between (a) the marginal transaction costs involved in regulating use *among* existing members of the commons (believed to rise with S (fall with n) and (b) the marginal exclusion costs of non-members of the commons (believed to rise with n).

A second extension has been recognition of the multi-dimensionality of property rights, for example in the case of land, the rights to use it, rent it, sell it, and the scope of those rights, i.e., the extent to which the apply to subterranean soil, minerals and water, surface water, and the air space over the land. Precisely because of the high transaction costs of monitoring and enforcing some of these rights, even in the most developed societies, such rights are typically incomplete. In other words, especially, with respect to some of these dimensions, the possessor is unlikely to possess all such rights without any external constraints or regulations.

---

12 See, e.g., Demsetz (1967).

The third extension has been empirical examination of the effects of such property rights. This is important because only in the naive version of the theory (i.e., without transaction costs and other kinds of externalities) would the creation of property rights necessarily imply the creation of net benefits over costs. In the context of land in rural areas of LDCs, these benefits have usually been assumed to take the form of (1) an incentive to avoid overuse and hence to maximize the economic rent derived from the land, (2) an incentive to invest in the land to increase its future productivity, and (3) the usefulness of a land title as collateral for investment-enhancing credit. Somewhat surprisingly (at least to some), empirical assessments have not always confirmed the alleged advantage of completely defined and individual praperty rights (with land titles) over less completely defined rights.[13] This has stimulated considerable search for explanations (apart of course from prohibitive transaction costs) for the less than complete property rights. One such explanation is that there may be several previously ignored benefits of incomplete property rights, such as that there may be information and efficiency advantages if the community as a whole is able to determine at each point in time and based on its accumulated information who is most deserving of access (Migot-Adholla et al.). Another suggested by Hoff and Lyon (1993) is that communal control may allow for more effective control of the moral hazard problems inherent in the various contractual relations within the community, especially those with respect to credit, which otherwise could result in market failure. A third and more popular explanation is the second-best argument that some higher level institutional or legal constraint (perhaps justified at one point in history) prohibits the attainment of the first-best (complete property rights).[14]

Our tack is to further develop another extension which has recently been initiated, namely the relevance of income risk, deriving from (exogenous) variations in environmental circumstances,[15] This approach starts from the proposition that the optimal property rights regime should depend not only on transaction costs and the expected value productivity of land (as in the now standard theory) but also on the variance in such productivity over space.

13 See especially Migot-Adholla, Hazell, Blare1 and Place (1991).

14 See for example the survey of such arguments by Eggertsson (1990).

15 See especially McCloskey (1976, 1989), Behnke (1984), Bromley and Chavas (1989), Sanchez and Nugent (1993) and Wilson and Thompson (1993).

Consider the intertemporal variance in land productivity of a given region (R) which is formed by pooling two subregions, 1 and 2, and which is defined by:

$$\sigma_R^2 = \sigma_1^2 + \sigma_2^2 + 2r\sigma_1\sigma_2 \quad (1)$$

Clearly, the overall variance depends in part on the correlation in the variations of such productivity between the two subregions of R, i.e., r_{12}. When several subregions, each having the same variance (σ^2), are pooled to form a single region, the average variance per unit of land in that region can be expressed as:

$$\sigma_R^2 = [\sigma^2/m][1 + (m-1)r] \quad (2)$$

where r is the mean of all pairs of correlations between the respective variations in rainfall in the m different subregions.

Clearly, when $r=1$, $\sigma_R^2 = \sigma^2$, indicating there would be no risk reduction advantage in land pooling. Yet, when $r < 1$, σ_R^2 declines as m rises and also as r falls, thereby suggesting that land pooling could be advantageous.

In the latter case and in the absence of well-developed insurance markets, a rational but risk-averse rural LDC household would be interested in diversifying some of its environmental risks by taking advantage of the less than perfect correlation between the variances on different subregions within region R. If the risk-reducing advantages of land pooling would come only at a certain cost in terms of expected productivity, e.g., as a result of the time it would take to, move the locus of productive inputs from one subregion to another, this would imply the existence of a transformation function with respect to expected productivity and its variance as a result of the degree of land pooling.

The optimal degree of land pooling would also depend on individual preferences with respect to expected output and risk. The risk premium anyone would be willing to pay would depend on his coefficient of risk aversion and the variance in productivity. As Newbery (1989) has shown, under reasonable assumptions about the shape of the utility function, the risk premium could be approximated by: $\rho = (A/2)\sigma^2$, implying that the coefficient of risk aversion would be a constant, and the optimal degree of land pooling (measured by m) would be determined by the point of tangency between the transformation curve and the slope of the rural household's utility function given by $d\sigma^2/d\mu$ as shown in Figure 1.

More specifically, the household could be assumed to maximize a utility function containing both an expected productivity term (μ) and a risk term (σ^2):

$$U = U[\mu(m), \sigma^2(m)] \qquad (3)$$

where both terms are functions of the number of pooled plots to which the individual household might have access. Following McCloskey (1976) and Thompson and Wilson (1994) in assuming that each of the m plots or subregions within region R has the same size, average yield and variance (but not necessarily the same covariances[16]) and that there are H hectares in the region, the expected productivity of the land endowment (μ_m) could be written as:

$$\mu_m = H\gamma(H/m)^{\eta} \qquad (4)$$

where η represents the elasticity of expected productivity with respect to the land endowment per plot, i.e., plot size. Clearly, expected productivity is inversely related to the number of plots in the pool m and directly related to both the size of the land endowment H and its productivity indicated by the parameter y.

Under these same assumptions, from equation (2) σ_R^2 would become:

$$\sigma_R^2 = [H^2 \sigma^2/m][1+(m-1)r] \qquad (5)$$

Since both (4) and (5) are functions of the choice variable m, as indicated in the figure, as in 'Figure 1, m could be chosen-in such a way that the marginal rate of substitution along the transformation frontier between variance and expected productivity would be made equal to the coefficient of risk aversion from the utility function (3).

Algebraically, $d\sigma^2 / d\mu = A = (-\delta\mu/\delta m)/(\delta\sigma^2/\delta m)$

16 If the plots vary oignificontly in quality, the problem could become somewhat more complicated. In this case, individuals would much prefer to obtain plots with low variance and high yields and one might expect considerable bargaining over the rules. In practice, however, for most of Sudan at least, although yields vary with soil type within a small region, the variances seldom do since they are subject to the similar influences like rainfall and flooding.

which from equations (4) and (5) can be rewritten **as**:

$$A = [\gamma\eta(H/m)^{1+\eta}]/[H^2\sigma^2(r-1)/m^2] = [\gamma\eta(H/m)^{\eta-1}]/(\sigma^2(r-1)) \qquad (6)$$

Alternatively, (6) can be rewritten as an expression for the optimal number of pooled plots, m^*

$$m^* = H[[A\sigma^2(r-1)]/\gamma\eta]^{(1/1-\eta)} \qquad (7)$$

Clearly, the optimal number of pooled plots or the degree of diversification of the portfolio of different land parcels would be positively related to the coefficient of risk aversion, and the extent to which diversification reduces risk (indicated by r-l) and inversely related to the productivity and productivity loss parameters γ and η, respectively. **Note** that both the basic productivity benefit of individual property rights (which would result in a small m) and all the important extensions of the basic theory, such as the transaction costs, reflected in η and the environmental risk elements reflected in σ^2 and r, appear in this formulation.

This formulation yields the following testable hypotheses:

(H1) The higher the productivity or scarcity value of the land (y), the lower will be **m**.

(H2) The higher the efficiency or transaction cost loss due to diversification reflected in η, the lower will be m.

(H3) The higher the value of σ^2 and the lower the **value of r, the larger will be m.**

(H4) Since for given land quality the productivity of the land **can be affected the basic type** of **land use, i.e.,** value productivity in agriculture generally being higher than in animal husbandry, **due in part to its lesser use of labor and** other resource inputs, **a choice of animal husbandry over agriculture (at least as** practiced in semi-arid areas of **LDCs** like Sudan) would generally have the effect of lowering γ **and thereby raising** m. By contrast, **the selection of agriculture over animal husbandry would lower m.** Another reason for the hypothesis is that there **are qreater external economies of scale in animal husbandry rather than in agriculture,** implying a lower value of η.[17]

---

17 See Nugent and Sanchez (1989, **1993) and Sanchez and Nugent (1993).**

Closely related to the issue of property rights in land is the degree of centralization or hierarchy in the society. Two different explanations for hierarchy might be given:

(H5) Since hierarchy is costly, hierarchy may be possible only when there is a surplus which would be more likely on good agricultural lands than on dry grazing lands frequented by nomads.[18] Hence, centralization and hierarchy within a society could be expected to be higher when weather and other conditions are favorable to high value productivity and high population density as would typically be the case with better market conditions for output and greater scarcity value of land.

(Ii6) Since seasonality In production increases the importance of generating peak season surpluses for use in the trough season, greater seasonality would be expected to increase hierarchy (in part also to manage and allocate the surpluses).

(H7) Since different households typically specialize in different activities, and the production of both agricultural and animal products in close proximity can yield important negative externalities for one another, externalities which might be mitigated with centralization and hierarchy, hierarchy could be expected to be higher in regions where both agriculture and animal husbandry are practiced than in regions in which one of these activities is dominant.

III. Sudan's Tribes and Data

As mentioned in Section I above, several features of Sudan and its land use make it a rather ideal locus for testing some of the above hypotheses. Among-these advantages are that most of its land is divided into a number of exclusive tribal areas, the different areas having rather different property rights and other institutions, that land use (especially the relative importance of agriculture and animal husbandry) varies substantially from one region to another, as do rainfall and other environmental patterns and characteristics. Of particular relevance is the relatively large number and dispersion throughout the populated portions of the country of meteorological stations with relatively long time series on monthly and annual rainfall data. Other advantages noted above are the relative stability

18 See especially Barth (1960), Salzman (1967, 1979), Gellner (1990).

of tribal land areas and institutions over time, especially since the late 19th Century, and the large number of rich ethnographic studies that have been conducted at one time or another on many of Sudan's larger and more important tribes. The relative stability of the institutional conditions in Sudanese tribes is important because otherwise it would have been impossible to obtain the relevant information on even the modest cross sectional sample of tribes utilized in this study.[19]

Despite these important advantages, this does not mean that the required data to carry out the analysis are immediately available. Indeed, a major part of the research on which this study is based involved combing existing ethnographies and other studies for at least minimal information for constructing at least crude indicators of the variables identified below. *Moreover,* to operationalize any of these variables calls into question the appropriate unit of analysis. Since land use and other characteristics are often rather common to the various divisions of the tribe, though in many cases rather different between tribes, we have taken the tribe to be the basic unit of analysis. Yet, despite years of discussion, there remains considerable dispute on whether the tribe is a more fundamental unit for these or other purposes than some of the suggested alternatives, such as the band, the community, the cultural unit or speakers of the same language. Moreover, there also remains considerable controversy over even the very definition of tribe. Indeed, even within our investigation of the various tribal groups in Sudan, we confronted frequent inconsistencies among analysts in terms of whether a particular tribe was viewed as a tribe or alternatively as either a division of a larger tribe, or a confederation or grouping of separate tribes.

Table 1 lists the forty-one societies treated as tribes and as the units of analysis for this study. While many of these are rather standard, in the sense that all analysts refer to them as tribes, there are some rather controversial ones as well. Among these are the Humr, which is sometimes treated as a division of the Messeriya tribe, and the **Nuba,** Dinka and Nuer, all of which are sometimes

19 This arises from the fact that the ethnographic and other studies from which the relevant information on the different Sudanese tribes has been obtained were quite naturally not undertaken simultaneously. The relative stability advantage is of course only relative, and some characteristics (such as population size and number of animal units) changed rather significantly over time. For this reason, whenever practical, we have tried to obtain estimates for the late 1930's.

referred to as tribal groups rather than as individual tribes. Each of the latter is treated here as a single tribe because of remarkable similarities in institutional and other characteristics among their various divisions and their common historical experience,[20] Their location within Sudan can be seen from the map presented in Figure 2.

Our presentation begins with a brief description of the endogenous variables and then goes on to the measures of the exogenous explanatory variables. With respect to the indicator of diversification (m in the model presented in Section II), we use an indicator called openness (OP). By this measure we mean the right of individual households to use land virtually everywhere within the tribal area (in Sudanese terminology the "dar"). Naturally, such a characteristic is not easily quantifiable and, as suggested above, because of the multidimensionality of property rights and the variation in rights of access by types of activity and time of year etc.,[21] its construction requires that a weighting of the different dimensions be performed. Given the incompleteness of information on all the relevant dimensions and the varying relevance of the different dimensions for different tribes, this weighting was admittedly rather ad hoc and subjective,

We illustrate the way in which the index shown in the column for OP, i.e., column 1 of Table 1, was constructed by reference to some of the more extreme cases. On the high end of the scale with scores of 90 or 100 are nomadic societies like the Bisharin, Hadendowa, Kababish and Turkana, whose institutions are such that virtually every household has the right to take its animals virtually anywhere within the tribal dar, irrespective of clan, age group, or residential group.[22] Even in these societies, there are exceptions in that, where cultivation is practiced within these territories, the herders are required to respect and hence keep their animals off crops which have been planted but not yet harvested. At the bottom end of the scale are societies like the Fur, Nuba, Shilluk and Zande where agriculture dominates and where the property rights are essentially private and rather unrestricted, inclusive of the right to rent or sell the land.

20 This judgment is based largely on Nadel (1947).

21 See especially Bailey (1992) and for Africa Migot-Adholla et al (1991).

22 Moreover, even in some of these cases, there seem to be differences of opinion among those doing studies on these tribes as to whether or not these conditions prevail. Compare, e.g., the characterizations of the Turkana by Barbour (1961), Gulliver and Gulliver (1953) and Lebon (1965).

As articulated in (H5-H7) above, a second institutional characteristic which varies across the tribes, and which for reasons indicated above we deem deserving of explanation, is the degree of centralization of control and hierarchy in the society. As noted above, this characteristic is closely associated, and perhaps even jointly determined with openness. This is because the stronger is the power and independence of a tribal leader, the more likely it is that the rights of access or openness will be restricted or at least vulnerable to future restriction. Also, the greater the hierarchy in the society, such as that among different clans, come being more "noble" than othcrc, the more likely that landed property and other resources would be concentrated in the hands of the few, thereby depriving many other households in the society from access to land (especially high quality land) and other resources. Our estimates of this index are given in the second column labeled (C). At the high end of this scale with scores of 80 and above are societies like those of the Zande and Shilluk which are highly stratified, in both cases with a king or noble chief at the top with considerable independent power. At the low end of the scale, with scores of O-20, are chiefless and hierarchy-lacking tribes like the Amarar, Fur, Toposa, Turkana and Nuer (the latter being especially well-studied and cited in much of the literature as the case *par-excellance* of such a society)[23].

In the third column of Table 1, though with many missing entries, is the number of animal units (AU). Since different tribes tend to specialize in different kinds of animals, some being much larger and more valuable than others, the following weights are used for aggregating the numbers of different animal types: cattle = 1.0, camels = 1.5, goats and sheep = 0.167.[24] Since most of the missing observations are for tribes for which animal husbandry is rather unimportant, the relevant hypothesis is that a higher value of the openness index (OP) should be positively related to AU. This expectation is based on the greater importance of the aforementioned advantages of common property rights and flexibility of access to different land areas within a region in, the face of local

23 See especially, Evans-Pritchard (1940), Bates (1983) and Middleton and Tait, eds. (1958).

24 While this weighting scheme is rather standard, it should be admitted that, especially among cattle, there are major differences in size, weight and value from one region to another, depending on both breed types and ecological conditions.

variability of rainfall in the case of grazing than in the case of agriculture. The relation could of course go the other way around, from AU to OP as discussed below.

The relevance of the choice between agriculture and animal husbandry as the primary activity to the other institutional choices has already been identified. In column 4 is an index of the percent of agriculture in aggregate tribal economic activity (PAG). Once again, there is considerable variation over the tribes in the sample, with the Zande, Fur, Jur, Acholi and Uduk at the high end and the Bisharin, Rababish, Rashaida and Turkana at the low end.

Next we turn to the indicators of inter-tribal variation in environmental conditions. Column 5 contains the mean monthly rainfall in tens of millimeters (averaged over the largest possible number of years) for weather stations in or near that tribal dar (RM). A high index of RM would imply greater land productivity and hence a lower value of m and hence openness (OP) and possibly also a higher value of the centralization index (C) due to the greater importance of investments in land, and economic surplus. These range from less than 100 for Bisharin territory in the far north and only slightly over 100 for the Amarar, Beni-Amer and Rashaida in the fairly far North to over 1000 in the hilly regions of the South.

Similarly, and again from the rainfall stations in or near each tribal dar, as an index of rainfall seasonality, in column 6 we present an average of the ratio of difference between (a) the average monthly rainfall of the three highest rainfall-months..and (b) .that.of.the.three lowest rainfall.months to the monthly average over all months. This variable is labeled RS. As can be seen, the value of this index ranges from lows of a little over 1 for some of the tribes living in the high rainfall areas of the South (such as the Acholi, Fajelu and Zande) to highs of close to 4 for the tribes living in the arid North where the limited rainfall is confined to a very few months of the year. As suggested in (H6) a high value of RS, would be expected to be associated with a high value of C so as to coordinate storage of the peak-season production surplus for use in the trough season and/or massive interregional migration between seasons.

The next rainfall-related measure (presented in column 7) is the coefficient of variation in annual rainfall over time (RCV). In contrast to the other rainfall indicators which are built up from the individual time series for the 168 rainfall stations, the source of this data is a special monograph on this subject [El Tom (1975)]. As shown in column 7, these indicators of intertemporal variability in rainfall vary from lows of less than 10% in the Southwest to 100% in the Northeast where the Bisharin live. The higher the intertemporal coefficient of variation (RCV), the higher should be the expected advantage of diversification (and hence the value of OP) and the expected disadvantage of centralization (i.e., lower value of C).

The final rainfall-related variable is the average coefficient of correlation in the monthly rainfall observations between adjacent or nearby pairs of rainfall stations. The values of this index are presented in the eighth column and labeled RDIST. Since the space between rainfall stations varies considerably, the correlation generally falling with distance, it is important to standardize this index for distance. This is done by the following formula: RD = $(DIST/100)^{1/2}$RDIST with the data for average distance between rainfall stations presented in the last column of the table (labeled DIST). As has been emphasized abave, the resulting standardized correlation coefficient (RD) would be expected to have a negative effect on OP and a positive effect on C.

In the next two columns of Table 1 are estimates of the tribal population and size of the tribal dar (or area within which that is used rather exclusively by members of the tribe in question). The former is measured in thousands of persons, wherever possible excluding the population of towns within these dars which may contain members of other tribes and in which the primary employment activities are neither agriculture nor animal husbandry.[25] The latter is measured in thousands of square miles. The primary use of these data is to compute population density (DENPOP), which as noted above is generally considered an important determinant of both the scarcity value of land and the emergence of (private) property rights.

The final measure included is a dummy variable for river (RIVER). If there were (a) several rivers or (b) a major river flowing in all seasons of the year or

25 As mentioned above, tribal population was a characteristic which in general was far from constant over time. In this case, therefore, we deemed it relevant to center the data on the late 1930's and extrapolate forward or backward to that date based on what was know about population growth rates in the same general vicinity.

(c), even if not (b), much of the tribal dar was close to the river(s), a value of 1.0 was assigned for RIVER. If there were one or more rivers, but not in close proximity to much of the tribal area, a value of 0.5 was assigned. Finally, if the tribal area was without a river of any consequence, a value of 0 was assigned. The effect of RIVER on OP would be expected to be negative and that on C positive.

IV Empirical Results

Empirical estimation of the relationships identified in H1-H7 above, in particular among the degree of openness (OP) and the degree of centralization or hierarchy in the society (C) and the explanatory environmental variables identified above (PAG, AU, DENPOP, RM, RS, RD, RCV, and RIVER) is severely plagued by two problems: namely, multicollinearity and potential simultaneity among the variables.[26] In order to mitigate these problems, we have had to: (1) be selective in the variables included in any one regression specification, (2) define the relevant variables to be as exogenous as possible (especially with respect to PAG and AU), and (3) recognize the possibility of joint determination between OP and C and the need to satisfy the rules of identification (again by being parsimonious with respect to the right-hand side variables included in each equation).

First, in the spirit of objectives (1) and (2), and because of its many missing observations, we exclude AU from the determination of OP and C, though as indicated below we assume that AU/POP could be affected by OP.

Second, since the choice between agriculture and non-agriculture (PAG) might not be entirely exogenous to institutional choice, we first estimate a reduced form equation for PAG and then use the results of this equation in estimating the equations for OP and C. The results of the reduced form equation for PAG are given in column (1) of Table 2. As can easily be seen, the explanatory power of the model is reasonably high (R^2 = 0.593). The coefficients of all the explanatory variables have the expected signs, although only those of RM, RD and RS are

26 For example the correlation coefficient between OP and PAG is -.89, and those between PAG and both RM and RD and also between RCV and both RM and RS are above .70 in absolute terms.

statistically significant at the 10% level and only the latter two at the 5% level.

From the aforementioned correlation matrix and the results of the PAG equation it is clear that the tribe-specific values of the predicted PAG (PAGHAT) would be closely related to the tribe-specific values of the significant explanatory variables, including the environmental ones whose effects on OP and c are the primary focus of the analysis. Yet, the residuals from this equation, i.e., PAGR = (PAG-PAGHAT), are much less closely correlated with the environmental variables. Also, since these residuals may represent the more genuinely exogenous, unobserved cultural and historical components of the choice between agriculture and animal husbandry of the different tribes, it is PAGR which is included among the other explanatory variables in the regressions for OP given in columns (2) and (3) and in that for C in column (4) of Table 2. In the case of C, however, as mentoned above, a perhaps more relevant determinant is the extent to which agriculture and animal husbandry would be practiced in close proximity to one another. For this purpose, in the regressions for C in both columns (4) and (5) we use a dummy variable for a value of PAG ranging from 30 to 70 (PAGDUM).[27]

The 2SLS estimates of a simple version of the estimating equation for OP are given in column (2) of the table. Note that, with the exception of RCV, the signs of the coefficients of all the explanatory variables are as expected and the exceptions statistically insignificant. Given its insignificance, the results reported in column (3) are with RCV omitted. Its omission is seen to have little effect on the other results. Something of a surprise, however, is that, as indicated by their respective T--values; in each of the three OP regressions, the effect of the variable of special interest in this paper, i.e., the distance-standardized average correlation coefficients of monthly rainfall observed at nearby meteorological stations (RD), is slightly more statistically significant than either mean rainfall (RM) or population density (DENPOP), the variables traditionally believed to be the primary determinants of property rights and hence OP. Note also the strong (and highly significant) expectedly negative effect of

27 Although, in principle, for the reasons indicated above, it might be assumed that PAGDUM should be calculated from PAGHAT, it was found to make no essential difference whether PAGDUM was computed from PAG itself or PAGHAT.

PAGR on OP in all three regressions and the negative but not significant effects of CHAT.

In columns (4) and (5) we present the 2SLS estimates for the corresponding regressions for C. As suggested in H5-H7 above, the explanatory variables in regression (5) are PAGR, PAGDUM, OPHAT, RS, RCV, DENPOP, RIVER and, as suggested above, an interaction term between (I-RD) and RCV. For reasons given above, OPHAT, RCV and possibly its interaction with (l-RD) would all be expected to have negative effects on C. On the other hand, the effects of PAGDUM, RS, RD, DENPOP and RIVER on C would all be expected to be positive.

While most of the signs of the coefficients in column (4) are as expected, there are some notable exceptions such as PAGR, DENPOP and RIVER. None of the latter are statistically significant, however, and when PAGR and-RIVER are omitted as in the column (5) regression, the coefficient of DENPOP no longer has the "wrong" sign.[28] A possible explanation for the unexpected and weak results for RIVER is that most of the rivers are in the southern part of Sudan where water is generally less in scarce supply and indeed may make for greater rather than less mobility because of seasonal flooding.

Of particular relevance are the negative and generally fairly significant effects of OPHAT and RCV and the positive and significant effect of RD and RS on C in both of these regressions. Also note that the effect of PAGDUM is positive and significant at the 10% level. Despite the fact that RD has the hypothesized positive effect on C, when (1-RD) is interacted with RCV its effect is positive and significant. Remembering that RD has a negative positive effect-on OP and OPHAT a negative effect on C, it is clear that there are both direct and indirect negative effects of RD on C.

Although the major focus of the paper is on the determinants of OP and C, and especially on the effects of local variability of rainfall, in view of the fact that an implication of the institutional analysis of OP in the case of animal husbandry is that productivity should be higher when OP is high than when it is low. As at least preliminary evidence relevant to this implication in column (8) of the table we present the results of a simple regression of one index of productivity in animal husbandry, namely the number of animal units per capita

28 Clearly, however, it is still totally insignificant.

(AU/POP). As can easily be seen, the coefficient of OPHAT on (AU/POP) is positive and highly significant, thereby seeming to support the implication. It should be recalled, however, that there would be good reason for expecting there also to be a relationship going the other way, i.e., from AU/POP to OP. Since the result is only one of correlation, this could just as easily be interpreted as support for the reversed causality hypothesis than the improved productivity hypothesis identified here.[29]

V Conclusions

The purpose of this paper is to suggest that the local variability of rainfall and other environmental factors could contribute to our understanding of institutional choices, such as the degree of openness of access with respect to land within a tribal dar and the degree of tribal hierarchy or centralization. In Section II it was suggested that with its many tribes , most of which have their own exclusive tribal dars, and its relatively long time series data on monthly rainfall for a large number of rainfall stations, Sudan would appear to be an almost ideal country for testing the relevance of local variability of rainfall on tribal institutions. While objective, quantitaive data on the relevant features of the different tribes and their tribal dars doesn't yet exist, as exemplified by the indexes presented in Table 1 above, crude indexes for at least several of the relevant variables can be constructed from existing ethnographic and historical studies. This was done as described in Section III. When the resulting indices for environmental factors including both traditional determinants, like mean rainfall and population density, and non-traditional ones, like local variability of rainfall, -are used to explain variations in institutional characteristics across the sample of Sudanese tribes, the results (Table 2) reveal that the indicators of local variability of rainfall add considerably to the explanatory power of models already including various traditional determinants of such institutions. Moreover, in most specifications, the local variability of rainfall turns out to be a more important determinant of both openness of access to the tribal dar and tribal hierarchy than the traditional explanations. In this regard at least, moreover, the results are rather robust to alternative types of specification.

---

29 The role of AU/POP in explaining various kinds of institutional and other variables is featured in the work of Schneider (1979).

The results also provide evidence for the hypothesized interdependence between various societal choices, namely, those of the primary economic activity (agriculture or animal husbandry), property rights (reflected in the degree of openness of access to land within the tribal dar) and the degree of hierarchy or centralization.

Finally, taken together, the results are also supportive of the heretofore neglected advantage in animal husbandry of relatively wide access to tribal land by the various tribal members in situations characterized by high local variability of rainfall and other environmental conditions. Since such variability is relatively high for many if not most arid and semi-arid regions, the policy and other implications could extend well beyond the confines of the Sudan. Since such arrangements would be difficult to work out in a context in which all land is privately owned, at the least this implies that considerable caution should be exercised before prescribing (as is rather common) privatization as a solution to low productivity of the land and the alleged tragedy of the commons in poor arid and semiarid regions.

While as a result, these preliminary findings provide unexpectedly strong support for most of the hypotheses developed here, further research is clearly called for in a number of respects. First, since the sample of Sudanese tribes used here is small (41) and non-randomly chosen, it would be highly desirable to enlarge the sample. Second, given (1) that differing characterizations of some tribes included in the sample have been identified by different authors in the existing literature, and (2) that all the measures used have been constructed rather subjectively by the present authors themselves, it will be important to see whether or not our findings can be corroborated by others with the same sample of tribes but their own judgments about weights etc.. Third, it would be desirable to investigate the applicability of similar sorts of analysis to tribes and other groups in other countries or in the arid and semi-arid regions thereof. Fourth, it would be desirable to use a somewhat more complex analytical framework that would allow for the simultaneous determination of additional variables and further identify the direction of causality among the variables studied.

Aside from the inclusion of population density and mean rainfall, nothing has been done in this study to put the proposed explanations in this study in competition with serious alternative hypotheses. This means that the tests performed are only rather weak ones, carried out by comparing the hypotheses with the corresponding null hypotheses. For example, a whole set of alternative serious hypotheses derives from the idea the choices and actions of one tribe can influence those of others, at least over time, suggesting not only that institutional innovations may display certain geographic patterns, but also that the choices are not independent of each other.[30] While the analytic framework used here has treated every tribe as an independent decision making unit, important theories exist in the literature suggesting that the institutional and other choices of individual tribes are constrained by the types of institutions chosen by other tribes in their immediate vicinity, especially in those of greater military strength or linguistic similarity. Clearly, therefore, it would be highly desirable to supplement the variables included here, all of which pertain to the characteristics of individual tribes with those of other relevant tribes in the same vicinity.

Finally, for the reason that cross-section results may not apply in time series contexts, the relevant one for policy analysis, it would be highly desirable to study institutional change over time in at least a smaller set of tribes where such data may be available at quite different dates in history.

30 See especially Irons (1979), Khazanov (1984), Schneider (1979) and Gellner (1990).

Table 1: Cross Tribal Data on Institutional and Other Variables

TRIBE	OP	C	AU	PAG	RM	RS	RCV	RDIST	POP	AREA	RIVER	DIST
Acholi	33	30		90	1114	1.10	5	0.76	250	9.0	1.0	138
Amarar	80	20		20	179	3.15	05	0.35	30	20.0	0.0	130
Anuak	33	50		90	652	2.16	20	0.00	40	6.2	1.0	30
Bari	33	60	15	50	827	1.71	15	0.88	35	3.3	1.0	59
Beni-Amer	60	20		30	118	3.30	62	0.43	40	100.0	0.0	45
Berti	20	40		75	232	3.84	62	0.06	35	6.3	0.0	100
Bisharin	100	20		0	59	3.14	100	0.01	34	50.0	0.5	650
Bongo-Baka	10	50		80	734	2.45	15	0.79		3.0	0.0	160
Burun	10	40		80	788	2.14	15	0.62	26	5.5	1.0	101
Daju	10	40		80	545	3.00	37	0.84			0 0	40
Didinga	10	70		30	1114	1.40	5	0.76	5	1.0	1.0	188
Dinka	50	40		50	794	1.83	20	0.61	900	'10.0	0.5	300
Fajelu	10	60	5	00	1200	1.43	5	0.76	35	1.0	1.0	33
Farahna	20	50		80	297	3.10	25	0.81	30	6.0	0.5	67
Fur	0	10	0	100	900	3.16	62	0.86	16	2.5	1.0	77
Hadendowa	90	25		20	152	3.17	62	0.09	260	55.0	1.0	319
Humr	50	40	360	30	370	2.46	37	0.58	55	30.0	0.0	110
Ingassana	40	60		20	888	3.00	37	0.60	10	3.0	0.0	105
Jur	33	50		90	924	3.05	15	0.70	10	2.7	1.0	120
Jiye	80	20		30	560	2.70	13	0.50	4	1.0	0.0	100
Kababish	100	40	430	5	375	3.19	62	0.50	60	41.0	0.0	123
Kakwa	33	30	8	90	1161	1.43	5	0.79	45	3.0	1.0	161
Kresh	10	80		90	964	2.32	15	0.75	10	3.0	1.0	233
Kuku	10	40	6	75	809	1.64	5	0.79	16	0.3	1.0	131
Latuko	20	40	5	75	815	1.66	10	0.76	60	2.0	1.0	108
Lokoya	20	50	3	80	827	1.71	10	0.67	11	0.5	0.5	139
Mandari	50	50	35	60	811	2.02	10	0.67	26	a.2	0.5	304
Moru	33	50	4	70	727	1.71	15	0.67	20	1.3	1.0	170
Murle	33	30		50	777	1.67	15	0.68	19	10.7	1.0	180
Nuba	10	40		80	637	3.50	25	0.01	300	30.0	0.5	156
Nuer	60	10		25	650	2.44	25	0.65	300	50.0	1.0	150
Nyangbara	33	70	3	70	774	1.44	17	0.64	17	1.6	1.0	[illegible]
Rashaida	100	10	.	0	152	3.27	62	0.09	30	50.0	0.5	419
Rizeiqat	00	20	400	50	362	3.01	37	0.70	50	15.7	0.5	156
Rufaa	00	30		30	430	3.11	37	0.77	33	15.0	0,5	111
Shilluk	10	90	.	80	605	2.48	17	0.76	00	1,0	1.0	140
Toposa	80	10	100	20	627	1.45	5	0.40	30	4.0	1 0	235
Turkana	99	0	445	5	350	1.46	47	0.40	60	26.0	0.I,	108
Uduk	20	60		90	610	2.77	15	0.19	I0	,0.6	I,0	140
Zaghawa	50	30	140	30	258	3.61	85	0.46	25	11.6	0.0	154
Zande	10	90	0	95	1026	1.60	5	0.73	750	50.0	0.5	190

Sources: Sea taxt and Appendix

Table 2

Regression Results for PAG, OP, C and AU/POP

Explanatory Variables	(1) PAG	(2) OP	(3) OP	(4) C	(5) C	(6) AU/POP
PAGR		-.656	-.660	-.290		
		(4.70)	(4.72)	(1.20)		
PAGDUM				5.539	5.431	
				(1.97)	(1.99)	
OPHAT				-.597	-.300	.158
				(2.06)	(1.70)	(5.86)
CHAT		-.429	-.375			
		(l-44)	(1.29)			
RM	.045	-.034	-.026			
	(1.99)	(2.27)	(1.97)			
RS	27.588			16.994	19.287	
	(2.50)			(2.02)	(2.38)	
RCV	-.434	-.207		-1.304	-1.286	
	(1.39)	(1.07)		(2.98)	(2.98)	
RD	41.417	-40.202	-43.824	38.921	54.230	
	(2.34)	(2.15)	(2.40)	(1.97)	(2.20)	
DENPOP	.364	-.281	-.239	-.089	.003	
	(1.41)	(1.39)	(1.20)	(.00)	(.01)	
RIVER	13.180			-5.307		
	(1.30)			(.64)		
RCV(1-RD)				1.269	1.161	
				(2.70)	(2.62)	
CONSTANT	-70,592	119.594	102.462	14.540	38-483	-3-411
	(2.10)	(6.65)	(12.29)	([illegible])	(1.46)	(3.18)
R^2	.593	.742	.732	.502	.496	.696
R2	.521	,696	.694	.384	.390	.676
N	41	41	41	41	41	16

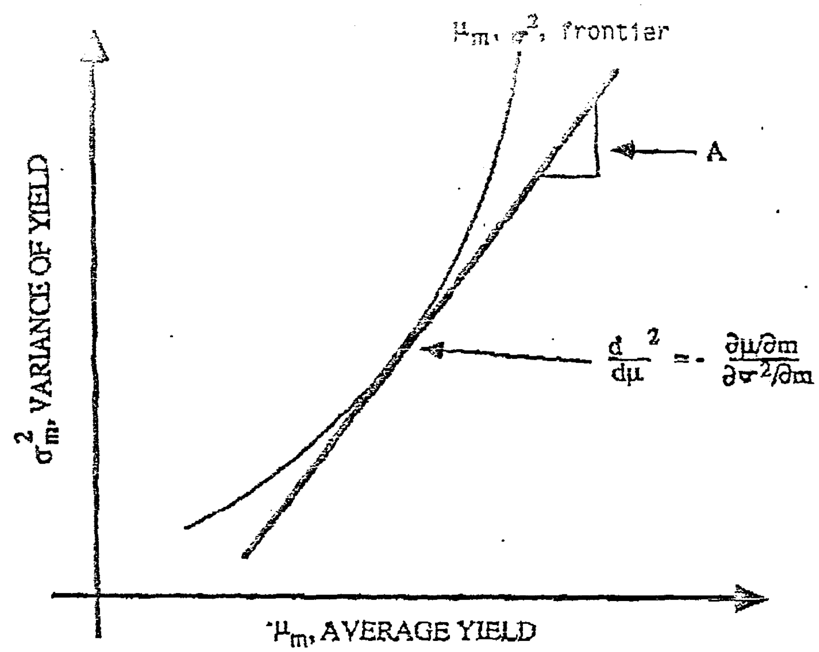

FIGURE 1. TRADEOFF BETWEEN AVERAGE YIELD AND VARIANCE OF YIELD

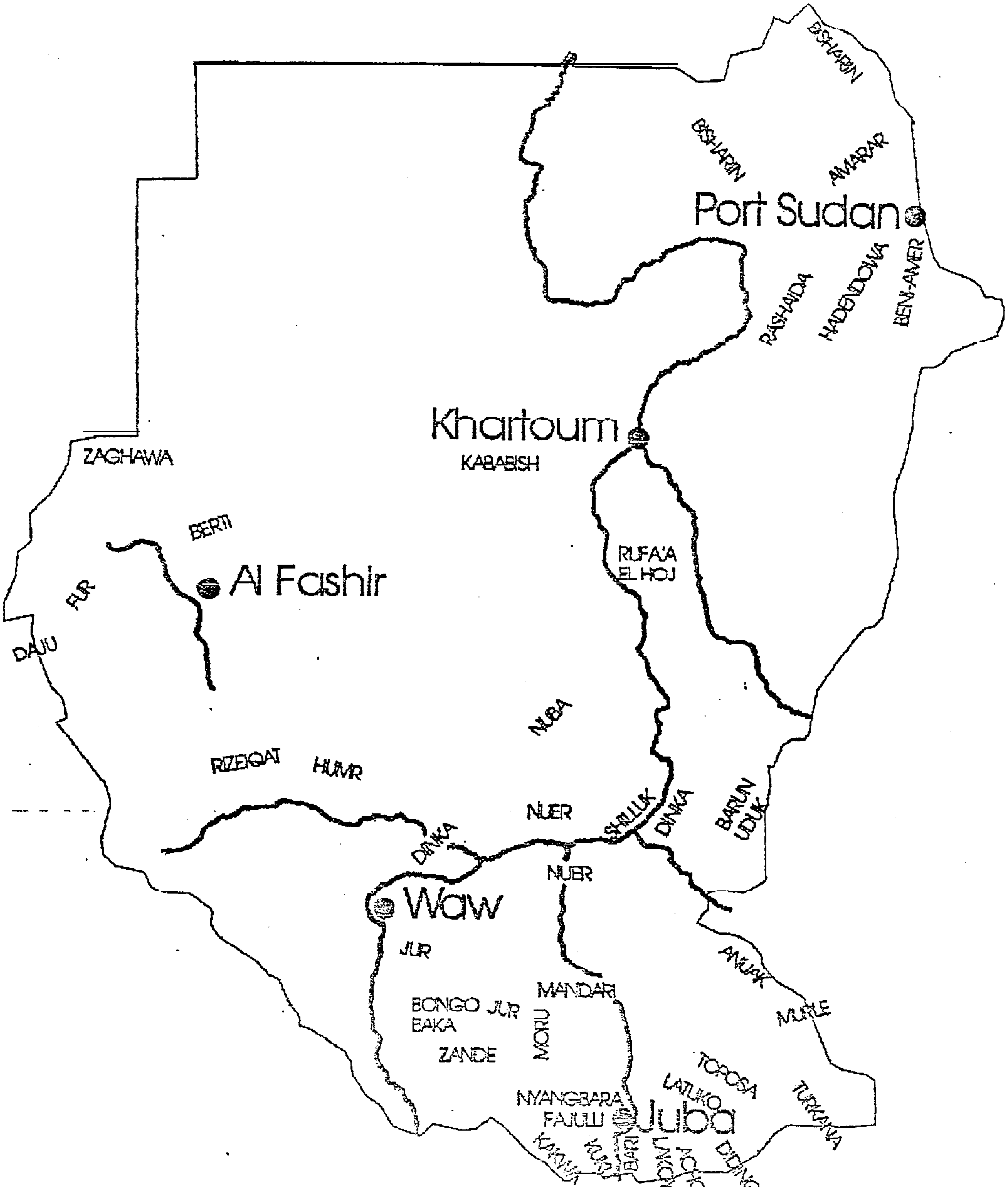

Figure 2. Tribal Map of Sudan

APPENDIX

SOURCES OF INFORMATION FOR CLASSICATION OF THE VARIOUS TRIBES

Tribe	Sources
Acholi	Barbour 1961; Butt 1964; Lebon 1965
Amarar	Cooper and Schoedsock 1929; Sandars 1935
Anuak	Barbour 1961; Wall 1976; Butt 1964
Bari	Barbour 1961; Huntingford 1953; Seligman and Seligman 1965
Beni-Amer	Barbour 1961; Paul 1950; Sadr 1991
Berti	Barbour 1961; James 1972
Bisharin	Sandars 1933; Barbour 1961; Lebon 1965
Bongo-Baka	Baxter and Butt 1953; Seligman and Seligman 1965
Burun	Butt 1964; Seligman and Seligman 1965
Daju	Barbour 1961; Tothill 1948; Seligman and Seligman 1965
Didinga	Seligman and Seligman 1965; Lebon 1965
Dinka	Barbour 1961; Deng 1972; Lienhardt 1958
Fajelu	Huntingford 1953; Barbour 1961
Ferahna	McMichael 1912, 1967; Lebon 1965
Fur	Barth 1962; Barbour 1961; Runger 1987; Lebon 1965
Hadendowa	Barbour 1961; Saleh 1980; Owen 1937; Lebon 1965
Humr	Cunnison 1966, 1972; Adams 1972; McMichael 1912, 1967
Ingassana	Lebon 1965; Seligman and Seligman 1965
Jiye	Gulliver and Gulliver 1953; Barbour 1961
Jur	Nalder 1937; Butt 1964; Barbour 1961
Kababish	Barbour 1961; Asad 1970; McMichael 1912,1967; Sadr 1991
Kakwa	Huntingford 1953; Seligman and Seliman 1965; Lebon 1965
Kreish	Santandrea 1968;
Kuku	Huntingford 1953; Barbour 1961; Seligman and Seligman 1965; Lebon 1965
Latuko	Huntingford 1953; Barbour 1961; Seligman and Seligman 1965; Lebon 1965
Lokoya	Huntingford 1953; Seligman and Seligman 1965; Lebon 1965
Mandari	Buxton 1955, 1957; Lebon 1965
Moru	Baxter and Butt 1953; Barbour 1961
Murle	Lewis 1972; Barbour 1961; Lebon 1965
Nuba	Barbour 1961; Nadel 1947; Faris 1972; Bolton 1948
Nuer	Evans-Pritchard 1940; Bates 1983;
Nyangbara	Huntingford 1953

Rashaida	**Saleh** 1980; **Barbour** 1961; McMichael **1912,1967;** Lebon 1965
Rizeiqat	Adams 1982; Runger 1987; Lebon 1965
Rufa'a El Hoj	**Ahmed** 1972; McMichael 1967; Lebon 1965
Shilluk	Butt 1964; Wall 1976; **Barbour** 1961; Lebon 1965
Toposa	Gulliver and Gulliver 1953; **Barbour** 1961; Lebon 1965
Turkana	**Barbour** 1961; Gulliver and Gulliver 1953
Uduk	James 1972; Seligman and Seligman 1965; Lebon 1965
Zaghawa	Tubiana 1992; **Barbour** 1961; McMichael 1912; Lebon 1965
Zande	Baxter and Butt 1953; **Barbour** 1961; Seligman and Seligman 1965

REFERENCES

Adam, Farah H. 1977. "Agrarian Relations in Sudanese Agriculture: A Historical Review". **Sudan Journal of Development Research.** 1 (December)

Adams, Martin 1982 "The Baggara Problem: Attempts at Modern Change in Southern Darfur and Southern Kardofan (Sudan)" **Development and Change. 13, 259-289.**

Ahmed, Abdel Ghaffar Mohammed 1972. "The Rufa'a Al-Hoj Economy", in I Cunnison and W. James, eds. **Essays in Sudan Ethnography.** New York: Humanities Press, 173-188.

Anderson, J.R. 1970. "Rainfall Correlations in the Pastoral Zone of Eastern Australia", **Australian Meteorological Magazine. 18 (2),** 94-101.

Asad, Talal 1970. **The Kababish Arabs. New** York: Praeger.

Awad, Mohammed Hashim 1971. "The Evolution of Landownership in the Sudan", **Middle East Journal 25,** *212-228.*

Bailey, Martin 1992. "Approximate Optimality of Aboriginal Property Rights", **Journal of Law and Economics** 35 (April) 183-198.

Barbour, K.M. 1961. **The Republic of the Sudan.** London 1961.

Bardhan, Pranab K., ed., 1989. The Economic **Theory of Agrarian Institutions.** Oxford: Clarendon Press.

Barth, Fredrik 1961. **The Nomads of South Persia. The Basseri Tribe of the Khamseh Confederacy.** London: Allen and Unwin.

Barth, Fredrik 1962. "Economic Spheres in Darfur". , 149-174.

Barth, Fredrik 1973. "A General Perspective on Nomad-Sedentary Relations in the Middle East," in Cynthia Nelson, ed. **The Desert and the Sown: Nomads** in **the Wider** Society. Berkeley: Institute of International Studies, Research Series No. 21, 11-*21.*

Bates. Robert H. 1983. "The Preservation of Order in Stateless Societies: A Reinterpretation of Evans-Pritchard's *The Nuer*", in R.H. Bates, ed. **Essays in the Political Economy of Rural Africa.** Cambridge: Cambridge University Press.

Baxter, P.T. W. and Audrey Butt 1953. **The Asande and Related Peoples of the Anglo-Egyptian Sudan and the Belgian Congo.** London: International African Institute Ethnographic Survey of Africa **V.** 9.

Behnke Jr., Roy H. 1984. "Fenced and Open-Range Ranching: The Commercialization of Pastoral Land and Livestock in Africa" in J.R. Simpson and P. Evangelou, eds., **Livestock Development in Sub-Saharan Africa.** Boulder: Westview Press.

Behnke Jr., Roy H. 1985. "Open-Range Management and Property Rights in Pastoral Africa: A case of Spontaneous Range Enclosure in South Darfur, Sudan." London: Overseas Development Institute.

Bennett, John W. 1985. "The Political Ecology and Economic Development of Migratory Pastoralist Societies in Eastern Africa" in Donald W. Atwood, Thomas C. Bruneau and John G. Galaty, eds. **Power and Poverty.** Boulder: Westview, 31-60.

Binswanger, Hans P. and Mark R. Rosenzweig 1986. **Journal of Development** Studies. (April), 503-539.

Binswanger, Hans J, McIntire and Chris Udry 1989. Production Relations in Semi-Arid African Agriculture," in P. Bardhan, ed., **The Economic Theory of Agrarian Institutions.** Oxford: Oxford University Press.

Bolton, A.R.C. 1948 "Land Tenure in Agricultural Land in the Sudan" in Tothill ed., 1948.

Bromley, Daniel W. and Jean-Paul Chavas 1989. "On Risk, Transactions, and Economic Development in the Semiarid Tropics", Economic **Development and Cultural Change 37** (4) July, 719-736.

Butt, Audrey 1964. **The Nilotes of the Sudan and Uganda.** London: International African Institute, Ethnographic Survey of Africa, East Central Africa, Part IV.

Buxton, Jean 1955. "The Mandari of the Southern Sudan", in John Middleton and David Tait, eds., **Tribes without Rulers.** London: Routledge and Kegan Paul, 67-98.

Buxton, Jean 1957. "Clientship among the Mandari of the Southern Sudan", **Sudan Notes and Records 37 100-110.**

Buxton, Jean C. **1963. Chiefs and Strangers.** London: Oxford University Press.

Casimir, Michael J. 1990. "The Determinants of Rights to Pasture: Territorial Organization and Ecological Constraints" in M.J. Casimir and A. Rao, eds. Mobility **and Territoriality.** New York: Berg.

Collins, Robert 0. **1971. Land Beyond the Rivers: The** Southern Sudan, 1898-1918. New Haven: Yale University Press.

Cooper, M.C. and E.B. Schoedsock 1929. "Two Fighting Tribes of the Sudan", **National Geographic 56, 465-486.**

-**Cunnison,** Ian 1966. **Baggara Arabs: Power and Lineage in a Sudanese Nomad Tribe.** Oxford: Oxford University Press.

Cunnison, Ian 1972 "Blood Money, Vengeance and Joint Responsibility: The Baggara Case" in Cunnison and James, eds. 1972.

Cunnison, Ian and Wendy James, eds., **1972. Essays in Sudan Ethnography.** New York: Humanities Press.

Demsetz, Harold 1967. 'Toward a Theory of Property Rights," **American Economic Review Papers and Proceedings 57 (May), 347-373.**

Deng, Francis **Mading** 1972. **The Dinka of the Sudan.** New York: Holt, Rinehart and Winston.

Dole, Gertrude E. 1968. in June Helm, ed., **Essays in the Problem of *Tribe.*** Seattle and London: University of Washington Press, **83-100.**

Dyson-Hudson, **Neville** 1980. "Strategies of Resource Exploitation among East African Savanna Pastoralists" in. D.R. Harris, ed. 1980.

Eggertsson, Thrainn 1990. **Economic Behavior and Institutions.** Cambridge: Canbridge University Press.

El-Tom, Mahdi **Amin** 1975. **The Rains of the Sudan.** Khartoum: Khartoum University Press.

Evans-Pritchard, E.E., 1940. **The Nuer.** Oxford: Clarendon.

Field, Barry 1985. 'The Evolution of Property Rights," **Kyklos**

Frankenberger, Timothy R. 1986. 'Integrating Livestock into Farming Systems". **Human Organization. 45 (3), 228-238.**

Fried, Morton 1975. **The Notion of Tribe.** Menlo Park: Cummings.

Gellner 1990. "Tribalism and the State in the Middle East" in Philip S. Khoury and Joseph Kostiner, eds. **Tribes and State Formation in the Middle East.Berkeley:** University of California Press

Gilles, Jere L. and Jerome Cefu "Nomads, Ranchere, and the State: The Sociocultural Aspects of **Pastoralism"** in John G. Galaty and Douglas L. Johnson eds., **The** World **of Pastoralism: Herding Systems** in **Comparative Perspective. New** York: Guilford.

Giovinetto, M.B. 1972. "Relationships between Cloud Size and the Variability of Precipitation in Arid Lands with Reference to Water Resource Planning". Paper presented at the 22nd International Geographical Congress, International Geographical union, Montreal, 10-17 August.

Giovinetto, M.B. 1974. "Precipitation in Arctic and Antarctic Coastal Barrens", **Polar Deserts and Man.** Tucson: University of Arizona **Press, 13-22.**

Graham, Anne. 1969. 'Man-Water Relations in East-Central Sudan", in M.F. Thomas and G.W. Whitington, eds. **Environment and Land Use in Africa.** London: Methuen, **409-445.**

Gulliver, Pamela and P.H. Gulliver **1953. The Central Nilo-Hamites.** London: International African Institute

Gulliver, Philip H. **1955. The Family Herds: A Study of Two Pastoral Tribes in East Africa, the Jie and Turkana.** London: Routledge.

Haaland, Gunnar 1972. "Nomadisation as **an** Economic Career among the Sedentaries in the Sudan Savannah Belt", in Cunnison and James, eds. (1972).

Harris, David R. ad., 1980. **Human Ecology in Savanna Environments.** London: Academic Press.

Hayami, Yujiro and Keijiro Otsuka 1993. **The Economics of Contract Choice.** Oxford: Clarendon Press.

Hoff, Karla and and Andrew Lyon 1993. "The Sequencing of Land and Credit Reforms in Developing Countries: A Theoretical Perspective". Washington, D.C.: Institute for Policy Reform, IPR65.

Holy, Ladislav 1974. Neighbors and Kinsmen; A Study of the Berti People of Darfur. New York: St. Martin's Press.

Huff, F.A. 1970. "Spatial Distribution of Rainfall **Rates", Water Resources Research (February), 254-260.**

Huff, F.A. and W.L. Shipp 1968. **"Mesoscale** Spatial Variability in Midwestern Precipitation," **Journal of Applied Meteorology 7 886-891.**

Hulme, Mike 1990. "The Changing Rainfall Resources of Sudan" **Transactions of the Institute of British Geographers 15, 21-34.**

Hulme, Mike 1992. "Rainfall Changes in Africa; 1931-1960 to 1961-1990", International Journal of Climatology 12, 685-699.

Huntingford, G.W.B. 1953. **The Northern Nilo-Hamites.** London: International African Institute. Ethnographic Survey of Africa.

Hutchison, P. 197.0. "A Contribution to the Problem of Spacing Rainguages in Rugged Terrain", **Journal of Hydrology 12 (1),** 1-14.

Irons, William 1979. "Political Stratification among **Pastoral Nomads' in Pastoral Production and Society.** Cambridge: Cambridge University Press.

Jackson, **I.J. 1988. Climate, Water and Agriculture in the Tropics,** N.Y.: **Longman, Second** Edition.

James, Wendy 1972. "The Politics of Rain Control among the Uduk". on Cunnison and **James, eds., (1972).**

Johnson, Daniel M. and John 0. Dart 1982. "Variability of Precipitation in the Pacific Northwest: Spatial and Temporal Characteristics". Corvallis, Oregon: Water **Resources Research Institute, Oregon State University, WRRI-77**

Khazanov, A.H. 1984. **Nomads and the Outside World.** Cambridge: Cambridge University Press.

Kopytoff, Igor 1987. **The African Frontier: The Reproduction of Traditional** African **Societies.** Bloomington: Indiana University Press.

Krader, Lawrence 1975. The Origin of the State among Nomads", in **Pastoral Production and Society.** Cambridge: Cambridge University Press.

Lebon, J. H. **G. 1965. Land Use in Sudan.** Bude, England: Geographical Publications, Ltd..

Le Houerou, Henri N. 1985. **"Pastoralism", in R.W. Kates, J.H. Ausubel and M. Berberian, eds. Climate Impact Assessment. New York, London; Wiley, 155-185.**

Le Houerou, Henri N. **1989. The Grazing Land Ecosystems of the African Sahel.** London: Springer-Verlag.

Le Houerou and C.H. Hoste 1977. "Rangeland Production and Annual Rainfall Relations in the Mediterranean Basin and in the African Sahelo-Sudanian Zone" **Journal of Range Management 30 (3)** (May) 181-189.

Lewis, B. A. 1972. **The Merle: Red Chiefs and Black** Commoners. Oxford: Oxford University Press.

Lewis, I.M., 1968. "Tribal Society" in David L. Sills, cd., International Encyclopedia of the Social Sciences. New York: Macmillan and Free Press, V. 16.

Lienhardt, Godfrey 1958. "The Western **Dinka"** in Middleton and Tait, eds. Tribes **without Rulers. London; Routledge and Regan Paul, 97-135.**

Lin, Justin Yifu and Jeffrey B. Nugent 1994. "Institutions and Economic Development", in J. R. Behrman and T.N. Srinivasan, eds. **Handbook of Development Economics, v. 3,.** Amsterdam: North Holland Chapter 37.

MacMichael, H.A. **1967. A History of the Arabs in the Sudan.** New York: Barnes and Noble.

MacMichael, H.A. 1912. The Tribes of Northern and Central Hardofan. Cambridge: Cambridge University Press.

McCloskey, Donald N. 1976. "English Open Fields as Behavior Towards Risk", in Paul Unselding, ed., **Research in Economic** History 1, Greenwich, Conn..

McCloskey, Donald N. 1989. "The Open Fields of England: Rent, Risk and the Rate of **Interest, 1300-1815," in David W. Galenson, ed., Markets in History: Economic Studies of the Past.** Cambridge: Cambridge University Press.

McConkey, B.G., W. Nicholaichuk, and H.W. **Cutforth** 1990. **"Small Area Variability of Warm Season Precipitation in a Semiarid Climate", Agricultural Forest Meteorology 49 225-242.**

Middleton, John and David Tait 1958. "Introduction", in J. Middleton and D. Tait, **eds. Tribes without Rulers.** London: Routlcdgc and **Kegan** Paul.

Migot-Adholla, Peter **Hazell,** Benoit **Blare1 and Frank Place 1991. 'Indigenous Land** Rights Systems in Sub-Saharan Africa: A Constraint on Productivity?" **World Bank Economic Review 5 (1): 155-175.**

Monteverdi, **John Paul 1978. A Meteorological Analysis of the Variability of Precipitation in the Great Plains, U.S.A.** Berkeley: University of California Ph.D. Dissertation.

Murdock, George Peter 1959. "Evolution in Social Organization" in Betty J. Meggers, ed., **Evolution and Anthropology: A Centennial Appraisal.** Washington, D.C. : The Anthropological Society of Washington.

Nabli, Mustapha K. and Jeffrev B. Nugent 1989. The New Institutional Economics and **Development: Theory and Tunisian Case Studies.** Amsterdam: North-Holland.

Nadel, S.F. 1947. **The Nuba.** London: Oxford University Press.

Nalder, L.F. ed., 1937. **A** Tribal Survey of Mongalla Province. London: Oxford University Press (for the International. Institute of African Languages and Cultures).

Newbery, David **M.** 1989. "Agricultural Institutions for Insurance and Stabilization," in P.K. **Bardhan,** ed., **The Economic Theory of Agrarian Institutions.** New York: Oxford University Press, 267-296.

Nugent, Jeffrey B. Nugent and Nicolas Sanchez 1989. "The Efficiency of the Mesta Reconsidered: **A** Parable", Explorations in Economic History 26 261-284.

Nugent, Jeffrey B. and Nicolas Sanchez 1993. "Tribes, Chiefs and Transhumance: A Comparative Institutional Analysis", Economic Development and Cultural **Change** 42 (October), 87-113.

Oladipo, E. Olukayode 1987. "Some Features of the Growing Season Precipitation Fluctuations in the Interior Plains of North America" **Journal of Climatology 7** , 531-540.

Osborn, H.B., L.J. Lane, and V.A. Myers, 1980. "Rainfall Watershed Relationships for Southwestern Thunderstorms," **Transactions of the ASAE, 23** 82-91.

Owen, T.R.H. 1937. "The Hadendowa" **Sudan** Notes **and** Records 20, 183-208.

Park, Thomas K. 1993. "Ecology and Risk Management: Stratified Common Property and Flood Recession Agriculture" in T.K. Park, ed., **Risk and Tenure in Arid Lands.** Tucson: University of Arizona Press.

Runger, Mechthild 1987. **Land Law and Land Use Control in** Western **Sudan.** London and Atlantic Highlands. Ithaca Press.

Sadr, Karim 1991. **The Development of Nomadism in Ancient Northeast Africa.** Philadelphia: University of Pennsylvania Press.

Saleh, Mohammad Hassan 1980. "Hadanduwa Traditional Territorial Rights and Inter-Population Relations within the Context of " **Sudan Notes and Records** 61, 118-133.

Salzman, Philip Carl 1967. "Political Organization among Nomadic Peoples", **Proceedings of the American Philosophical Society** 111 **(2),** 115-131.

Salzman, Philip Carl 1979. "Tribal Organization and Subsistence: A Response to Emmanuel Marx" **American Anthropologist 81** (1) 121-124.

Sanchez, Nicolas and Jeffrey B. Nugent 1993. "Institutional Arrangements in Cattle-Raising Activities in the 19th Century American West and Their Explanation" Paper presented to the Western Economic Association meetings in Lake Tahoe.

Sandars, G.E.R. 1933. **"The Bisharin" Sudan Notes and Records- 16, 119-149.**

Sandars, G.E.R. 1935. **"The Ammarar", Sudan Notes and Records.** 18, **195-220.**

Santandrea, Stefano 1968. **A Tribal History of Western Bahr El Ghazal. Bologna: Editrice** Nigrizia.

Schneider, Harold **K. 1979. Livestock and Equality in East Africa: The Economic Basis for Social Structure.** Boomington: Indiana University Press.

Seligman, C.G. and Brenda Z. Seligman 1965. **Pagan Tribes of the Nilotic Sudan.** London: Routledge and Kegan Paul. (Reissue of book first published in 1932).

Sen, .Amartya K. 1981. **Poverty and Famines: An Essay on Entitlement and Deprivation.** Oxford: Oxford University Press.

Sharon, David 1972. "The Spottiness of Rainfall in a Desert Area", **Journal of Hydrology (November),** 161-175.

Sharon, D. 1974. "The Spatial Pattern of Convective Rainfall in Sukamland, Tanzania - A Statistical Analysis" **Archiv fur Meteorologie Geophysik Bioklimatologie.** Series B., 22 (3), 201-218.

Sharon, David 1979. "Correlation Analysis of the Jordan Valley Rainfall Field", **Monthly Weather Review 107, 1042.**

Sharon, David 1981. *The Distribution in Space of Local Rainfall in the Namib Desert", **Journal of Climatology** 1, 69-75.

Smith, Andrew B. **1992. Pastoralism in Africa: Origins and Development Ecology.** London: Harst; Athens: Ohio University Press.

Stol, P. T. 1972. "The Relative Efficiency of the Density of Rain-gage Networks", **Journal of Hydrology** (March) 193-208.

Taylor, Ralph B. 1988. **Human Territorial Functions.** Cambridge: Cambridge University Press.

Thompson, Gary and Paul N. Wilson 1994. "Common Property as an Institutional Response to Environmental Variability", **Contemporary Economic Policy 12** (July) 10-21.

Tothill, J.D., ed. 1948. **Agriculture in the Sudan Being a Handbook of Agriculture as Practices in the Anglo-Egyptian Sudan.** London: Oxford University Press.

Tubiana, Marie-Jose and Joseph Tubiana 1992. **The Zaghawa from an Ecological Perspective. A.A.** Balkema.

Wall, L.L. 1976. "Anuak Politics, Ecology and the Origins of Shilluk Kingship" Ethnology.15 (April) X1-162.

Wilson, Paul N. and Gary D. Thompson 1993. "common Property and Uncertainty: Compensating Coalitions by Mexico's Pastoral Ejidatarios," **Economic Development and Cultural Change** (January), 299-318.