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Title

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Permalink

<https://escholarship.org/uc/item/88h0d858>

Journal

American Anthropologist, 86(3)

ISSN

0002-7294

Authors

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Publication Date

1984-09-01

DOI

10.1525/aa.1984.86.3.02a00020

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Sexual Division of Labor in Agriculture

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Female agricultural contributions decline with agricultural intensification. We formulate and test a theory of the processes of agricultural intensification that explains a high proportion of the variance in female contributions to agriculture. Five variables show replicable effects across two or more regions of the world. These are number of dry months, importance of domesticated animals to subsistence, use of the plow, crop type, and population density. Of these, the first two are the most powerful predictors of female agricultural contributions, while population density has only very weak effects.

FEMALE CONTRIBUTIONS TO AGRICULTURE DECLINE WITH AGRICULTURAL INTENSIFICATION (Boserup 1970; Ember 1983; Sanday 1973). Study of this phenomenon has become an important research agenda, motivated by two major anthropological concerns: the cross-cultural study of gender roles, and the study of agricultural intensification. In the area of gender roles, recent research has provided evidence of important linkages between female subsistence contributions and such important customs as polygyny (Heath 1958; Burton and Reitz 1981), female initiations (Brown 1963), socialization practices (Whiting and Whiting 1975; Nerlove 1974), and female control over economic resources (Blumberg 1978; Sanday 1973). In the area of agricultural intensification, Boserup's focus on population pressure has provided a potentially powerful explanation for processes of societal evolution.

In this paper we develop an ecological explanation for variations in female agricultural contributions. We focus on both of the issues that have motivated concern with the Boserup hypothesis: gender roles and processes of agricultural intensification. We test and extend the explanation offered by Boserup (1970), adding variables for the importance of domesticated animals, crop type, and climate. In so doing, we reexamine anthropological thinking about the effects of tropical climate on social institutions, raising the question whether it is temperature itself, or some other aspect of the tropical climate, that causes high female contributions to agriculture.

PREVIOUS RESEARCH ON SEXUAL DIVISION OF LABOR IN AGRICULTURE

Modern cross-cultural research on sexual division of labor began with the work of Murdock (1937). Murdock and Provost (1973) expanded on this work by providing codes on

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sexual division of labor for 50 tasks for the Standard Cross-Cultural Sample (Murdock and White 1969). In explaining sexual division of labor, Murdock and Provost (1973:211) appeal to a masculine advantage for tasks requiring greater physical strength or "brief bursts of excessive energy," and a feminine advantage for tasks not requiring long absences from the household. In their discussion Murdock and Provost cite Brown (1970), who proposes that women tend to do tasks that are compatible with child care — tasks that are not dangerous, do not require distant travel, and are interruptible. They report a tendency for the sex that uses a product to be the one that produces it, and find correlations between female subsistence contributions and fixity of residence, occupational specialization, agricultural intensification, and the processing of animal products. They also note that use of the plow decreases female participation in agriculture.

D'Andrade (1966), in an earlier analysis of Murdock's 1937 data, notes a strong correlation between the use of cattle in farming and the participation of men in agriculture. As with later discussions of the role of domesticated animals and the plow in agriculture, however, D'Andrade does not offer an explanation for this correlation in terms of specific social processes.

Burton, Brudner, and White (1977) in an analysis of the Murdock and Provost data, find partial orderings of tasks within several production sequences, including livestock production, livestock products, fishing, and agriculture. They note that there tends to be only one change in sex participation within a production sequence, with male tasks near the beginning of sequences and female tasks near the end. The sequence for five agricultural tasks has especially strong statistical relationships: if women clear the land, they prepare the soil; if they prepare the soil, they also plant crops, tend crops, and harvest crops.

Boserup (1965, 1970) began much of the current discussion on agricultural intensification, proposing that population pressure causes shortening of the fallow and the introduction of the plow. The plow leads to increased male farming, partly because it increases the number of hired laborers, who tend to be male; partly because the plow reduces the amount of weeding for women to do; and partly because it is almost universal for men to do the actual plowing. Boserup states that intensive systems require more labor hours per person per week, and that much of this extra labor is spent caring for domesticated animals. Although the main focus of her work is on the transition to plow agriculture, she also discusses another type of intensification: the very intensive rice agricultural systems of East Asia. Noting the high female participation in this type of agriculture, she suggests that the overall relationship between female agricultural participation and intensification is curvilinear. We provide evidence pertaining to this assertion later.

Martin and Voorhies (1975), in discussing the Boserup hypothesis, note the strong correlation of male farming systems with cereal crop agriculture. They argue that cereal crops are more difficult to process than root crops. Hence, women must spend more time on food processing, leaving less time for agriculture.

Whiting (1964) discusses the effects of tropical climate and root crop agriculture on several cultural institutions, including polygyny, mother-child sleeping arrangements, postpartum sex taboos, and male initiations. We now know that several of these institutions are associated with high female contributions to subsistence (Burton and Reitz 1981; Heath 1958; Saucier 1972). As Whiting notes, these institutions are commonly found in the rainy tropics. It might seem that high temperatures explain the presence of these traits in the tropics (Lomax 1977). However, high temperatures and low female subsistence contributions co-occur in the Middle East, so this hypothesis does not seem plausible.

White, Burton, and Dow (1981) provide an alternative hypothesis concerning the ef-

fects of climate on the sexual division of labor in agriculture. They note that two common attributes of intensive agriculture—use of cereal crops and dependence on domesticated animals—are both correlated with the number of dry months per year. With many dry months and a shorter growing season there is more time pressure in planting and harvesting crops, and this increased time pressure may account, in part, for increased male participation in cereal crop agriculture. Maclachlan (1983) provides ethnographic data on a South Indian intensive farming system which support the seasonality hypothesis. He argues that a narrow “seasonal window” puts a premium on the labor of young men; the time pressure of soil preparation is so great that physically demanding tasks must be done very rapidly, and under these circumstances, the physical strength advantage of young men over all other members of the population makes them the best candidates for farm labor. Maclachlan reports that even the younger men are pushed to the limits of their physical capacities during the most time-pressured periods. Because critical agricultural decisions are made during these times, men gain farm management experience that women do not have. Hence, older men end up being the managers of family farms. So, in this case seasonality of production not only increases male labor inputs but also increases the power of men over women.

Ember (1983) argues that there are two separate processes involved in the decline of relative female agricultural contributions with intensification: increased female participation in domestic work and increased male participation in agriculture. She cites time allocation data published by Minge-Klevana (1980) that show major changes in the time allocation profiles of men and women with agricultural intensification. With intensification, women’s time on outside work, such as agriculture, remains constant at about 4 1/2 hours per day, but their time spent on inside work increases from about 3 hours to about 6 hours per day. By contrast, men’s inside work remains constant at about 1 hour per day, but their time spent on outside work, such as agriculture, increases from about 5 hours per day to almost 7 1/2 hours per day. We note that Boserup (1970) provides data for a number of extensive African and intensive Asian societies that support this finding. In Boserup’s samples the African men work 17.0 hours per week on agriculture, the African women, 15.4 hours per week, and the Asian women, 18.3 hours per week. There are no statistically significant differences among these three figures, but the Asian men’s figure—28.5 hours per week—is significantly greater than the other three.

Ember proposes three causes of the intensification of female domestic labor: more time spent on food processing because of the use of cereal crops (White, Burton, and Dow 1981); more time spent caring for the more complex, permanent household, including more time spent obtaining water and fuel; and more time spent on child care because children’s labor is more valuable in intensive regimes (Nag 1962; White 1973) and fertility is higher.

A number of authors have discussed causes of variability in male labor inputs to agriculture. In addition to arguments concerning population pressure (Boserup 1970), seasonality (White, Burton, and Dow 1981; Maclachlan 1983) or capital-intensive use of cattle (D’Andrade 1966), which are hypothesized to increase male participation, a number of hypotheses have been proposed about ways in which other male activities interfere with male agricultural participation. These other activities include hunting and warfare (Ember and Ember 1971; Sanday 1973), long-distance trade (Ember 1983), and labor migration (Sanday 1973; Levine 1970).

AGRICULTURAL INTENSIFICATION

Intensive agriculture is most often defined as agriculture using the plow, or irrigation, or both (Murdock 1967). However, as a number of recent studies have shown, agricul-

tural intensification is a multidimensional process that may occur in the absence of either the plow or irrigation. Boserup (1965) advances this viewpoint by defining intensification as shortening of the fallow by any method, and Netting (1968) provides an excellent description of intensification in the absence of the plow or irrigation. It is now recognized that intensification can include adoption of the plow or irrigation, building mounds (Waddell 1972) or terraces, pollarding (Richards 1939), green manuring, use of animal manure, transplanting (Geertz 1963), and increased use of animal labor. Given this multiplicity of processes, it is surprising that there appears to be no shared definition of agricultural intensification in the anthropological literature. Those who write about intensification seem to assume that the meaning of the term is clear and agreed upon. We define intensification, following Jochim (1981) and Cox and Atkins (1979), as any process that increases yield per hectare.

Economists see increased production as resulting from increased inputs of land, labor, capital, or technology. Holding land constant, we then see intensification as resulting from labor intensification, capital intensification, or technological change. Changes in agricultural technology usually involve transformations of the ecosystem that change the number and type of species and that modify the natural linkages among trophic levels. We discuss here these three components of agricultural intensification with their likely consequences for the sexual division of labor.

Labor intensification is aptly described in Geertz's (1963) classic work on wet rice agriculture. At every step of the agricultural cycle, higher yields can be obtained through greater labor inputs to such tasks as transplanting, weeding, and harvesting.

Labor intensification can produce a shift to male farming if the increased labor requirements exceed the time available to women after allowing for their inputs to domestic production, child care, and housework. Domestic tasks take time on an almost daily basis, so the relevant constraint on women is measured in hours per day. Hence, labor intensification is most likely to affect female participation in agriculture if it requires very high labor inputs per day on a seasonal basis. It is less likely to have such an impact if labor requirements are more evenly spread throughout the agricultural cycle. Hence, we hypothesize that seasonality of production will have strong positive effects on male agricultural participation.

Capital intensification is defined, for the purposes of this paper, in terms of permanent changes in the agricultural system that produce a stream of yields in the future. These changes can include building mounds, terraces, fences, or irrigation systems; permanently clearing land by removing roots and stumps (Boserup 1970); or digging wells. Capital intensification provides many of the physical traces of historical intensification processes that are available to archeology.

Capital intensification produces private property in land, agricultural implements, and draft animals. Capital intensification need not result in labor intensification; indeed, it may reduce labor inputs, as in Western mechanized farming. It may, however, increase male participation in certain tasks through its effect on the distribution of private property. To the extent that men monopolize ownership of draft animals and agricultural implements, they may seek to perpetuate that control by keeping the use of those productive factors out of the hands of women.

The plow is a particularly important form of capital intensive production that has been hypothesized to cause increased male agricultural participation (Boserup 1970; Goody 1977), monogamy (Burton and Reitz 1981; Goody 1977; Boserup 1970), and bilateral inheritance (Goody 1977). We hypothesize that use of the plow will increase male participation in agriculture, although not necessarily in all tasks (Burton and Reitz 1981). In studying the effects of plow agriculture, we feel it is important to distinguish between the

specific effects of use of the plow and more generalized effects of use of large domesticated animals for other purposes. Specifically, we discuss the role of domesticated animals in intensive ecosystems and the role of women in caring for domesticated animals.

Change in agricultural technology produces an increasingly artificial ecosystem, characterized by lower genetic diversity, shorter fallow periods, and a preponderance of fast-growing species that have been genetically altered by human intervention. Many discussions of agricultural intensification have focused on this aspect of intensification (Geertz 1963; Meggers 1971). Early discussions emphasized the relative stability of the genetically diverse slash-and-burn systems compared to intensive farming systems (Conklin 1957). However, at least one artificially created intensive system—wet rice agriculture—appears to be very stable (Geertz 1963; Cox and Atkins 1979), and there has been recent discussion of the relatively low diversity of crops in some swidden systems (Beckerman 1983). All agricultural systems modify the natural ecosystem to some extent, and some of these ecosystem transformations appear to have consequences for the sexual division of labor.

Ecosystem transformation destroys many natural ecological linkages by removing species from the system, and this destruction of linkages may produce instability. However, ecosystem transformations also add new linkages, which may restore stability to the artificial system. This usually involves altering the natural relationships between plants and animals. Chinese wet rice farmers, for example, often keep carp and feed them pig or silkworm feces (Zhong 1982). These linkages are not a part of a natural ecosystem, but are an important aspect of efficient biomass utilization in the wet rice system. Similarly, people who keep cattle and grow cereal grains commonly fertilize their crop with cow manure and feed the cattle on humanly inedible cereal byproducts. This linkage is not an important part of the natural ecosystem, but it is essential to many Old World intensive agricultural systems. In fact, dung production may be the most important reason to keep cattle (Hoffpauir 1978).

The use of domesticated animals in intensive farming systems appears to have important consequences for the sexual division of labor in agriculture. Previous discussion has focused mainly on the effects of the use of animals for traction (Boserup 1970; Goody 1977; Burton and Reitz 1981; Ember 1983). Animals, however, often play an important role as food sources, and many intensive systems lack the plow but make strong use of domesticated animals as part of the artificial ecosystem. We treat these two aspects of domesticated animals—their use as draft animals and their use as a food source—as separate variables in our discussion. As Harris (1966) has stated, these two uses may be incompatible in very intensive systems.

We have noted Boserup's suggestion that care of domesticated animals accounts for much of the increased labor inputs to intensive agriculture. Much of this work appears to be done by women and children, and we predict that an increasing proportion of this work will be done by women in those intensive agricultural systems that also have a high degree of dependence on domesticated animals. With intensification, animals spend more of their time close to the household, where they are more likely to be cared for by women. As intensification progresses, there is less pasture land, and more of the fodder is brought to the animals. As Hoffpauir (1978) notes, collecting fodder can take up to five hours per household per day. Maclachlan (1983) describes this process in some detail for his community of South Indian intensive agriculturalists. Women's weeding is such an important source of fodder that women consider provision of animal food to be the main goal of weeding. Other animal care tasks commonly done by women include gathering dung for fuel or building materials, bringing water for animals, milking and dairy production, preserving meat, caring for infant animals, and processing hides and wool.

These tasks, though often not very visible, can be very time consuming (Blumberg 1979).

Two examples from East African pastoral societies exemplify the use of women's labor in processing animal products. Maasai women build houses from wattle and cow dung and must spend considerable amounts of time replacing the roofs, especially in the rainy season. Where the first stages of adoption of agriculture have begun in the Loita Hills, women explain the recent replacement of cow dung roofs by grass roofs by saying that they do not have time both for agriculture and for maintaining the cow dung roofs. An even less obvious use of women's time, both for the Maasai and for the Orma of northeast Kenya (Ensminger 1983), is sterilization of milk calabashes. This takes about 30 minutes per calabash, and requires a special kind of wood, which is time consuming to collect. Women gather the wood, and with increasingly sedentary residence, wood collection becomes a serious problem.

Given these considerations, we hypothesize that increased dependence on domesticated animals will place a severe constraint on women's agricultural time and that very high amounts of dependence on domesticated animals will result in sharply curtailed female agricultural inputs. Hence, the ecosystem transformations of intensive agriculture may require increased female domestic labor for their maintenance.

We can provide three pieces of quantitative evidence for this hypothesis. The first comes from data reported by Nag, White, and Peet (1978). In Java, where the total time spent on domesticated animals is about 1.5 hours per person per day, more than 80% of the animal care is done by males. In the Nepalese sample, where the total time spent on domesticated animals is about 3.5 hours per person per day, males do only half of the care of domesticated animals. Javanese women over age 20 spend an average of 0.15 hours per day on animal care, but Nepalese women spend 1.93 hours per day on animal care. Furthermore, between ages 15 and 19, Javanese girls do no animal care at all but Nepalese girls spend 3.4 hours per day on animal care, compared to 2.8 hours for boys of the same age. Much of the difference in animal care time between the two samples is accounted for by the dramatically increased input from older girls and women.

The second piece of quantitative evidence is provided by Boserup's (1970:31) work load data for five Indian communities. Time spent by men in the care of animals varies little across the societies, ranging from 12 to 15 hours per week. By contrast, time spent by women caring for animals varies from 3 to 22 hours per week, and has a correlation of $-.83$ [$p < .05$] with time spent by women in agriculture. Hence, as care of animals increases, the increase is taken up by women, with a resulting decline in their time in agriculture.

The third piece of quantitative evidence comes from cross-cultural data on the sexual division of labor in milking and dairy production. Gamma coefficients between these variables and the form of land transportation are .80 and .46, respectively. In societies with draft animals or animal-drawn vehicles, women almost always do the milking, whereas in societies with human porters, men almost always do the milking. This relationship shows one effect of the intensified use of animals on women's work load. In societies that lack intensified linkages between animals and agriculture, animals can be spatially removed from the agricultural sector, and the men who travel with the animals can also milk them. In systems with intensified linkages between animals and agriculture, the draft animals tend to be kept near the fields and household, where women milk them.

SPECIFICATION OF THE MODEL

Our analysis specifies five variables that we hypothesize to affect the sexual division of labor in agriculture, either through increasing male participation in agriculture or through decreasing female participation.

Population pressure will cause labor intensification, and in its more extreme forms we hypothesize that population pressure will require increased male agricultural participation. Population pressure also leads to ecological degradation, making gathering water and firewood more difficult, and increased female involvement in these tasks may lead to decreases in women's agricultural participation. We measure population pressure using Murdock and Wilson's (1972) seven-point scale for population density.¹

We hypothesize that seasonal time pressure will cause increased male participation in agriculture. As a measure of seasonal pressure we use Whiting's variable for the number of dry months (Whiting, Sodergren, and Stigler 1982). We realize that there are other causes of seasonal pressure, most notably a long, cold winter, but there are few agricultural societies in our sample with long, cold winters, and many with long dry seasons. Table 1 shows the cross-tabulation of number of dry months with the division of labor in crop tending. We see that with no dry months only 16% of the societies have crop tending done entirely or mainly by males but that this increases to 78% when there are more than six dry months ($\text{Gamma} = -.55$). Gammas for the relationships of number of dry months with the divisions of labor in soil preparation, planting, and harvesting range from $-.40$ to $-.46$.

The third variable, presence of the plow, is hypothesized to increase male labor inputs to agriculture. We use a variable for the presence of the plow coded for the *Ethnographic Atlas* (Murdock 1967). In our sample of 137 agriculturalists, 32 societies have the plow.

We hypothesize two causes of increased female labor inputs to domestic production: a high degree of dependence on domesticated animals for subsistence, and the food processing requirements of cereal crops. Dependence on domesticated animals has two plausible effects. The first is a direct effect on the amount of time women spend caring for animals, which, as we have seen, can be quite high. A second possible effect is that domesticated animals increase the demand for children's labor, and hence the birth rate (Nag, White, and Peet 1978). If this is so, women should have higher child-care responsibilities. We use in our analysis a variable from the *Ethnographic Atlas* that measures the degree of dependence on domesticated animals for subsistence on a ten-point scale.

To test our hypothesis that female participation will be lower in cereal crop agriculture, we use a variable for crop type from the codes for subsistence economy (Murdock and Morrow 1970). There are three major crop types--tree, root, and cereal--and we treat them as three separate dichotomous variables.

The dependent variable, total female contribution to agriculture (AgTot), is a sum of four tasks from Murdock and Provost (1973): soil preparation, crop tending, crop planting, and crop harvesting. Each is coded on a five-point scale, so the resulting scale ranges

Table 1. Relationship between division of labor in crop tending and number of dry months.

Dry months	Crop tending		
	Male or mainly male	Equal, mainly female or entirely female	% Male
None	7	36	16
1-2 months	5	10	33
3-4 months	6	14	30
5-6 months	7	16	30
7-12 months	18	5	78

from 4 (all four tasks done entirely by men) to 20 (all four tasks done entirely by women).²

STATISTICAL ANALYSIS

We test the model using ordinary least squares regression analysis. Our strategy is to test the model on the entire world sample of agricultural societies for which we have adequate data on all variables ($N = 137$) and then to replicate the model on four major regions, as defined for the Standard Cross-Cultural Sample (Murdock and White 1969): Western Old World ($N = 46$) (Circum-Mediterranean and Sub-Saharan Africa), Eastern Old World ($N = 27$) (East Eurasia), Oceania ($N = 25$), and America ($N = 39$) (North and South America). We also test the model on an intermediate-level aggregation of these regions: the Old World ($N = 73$).

In our Africa study (White, Burton, and Dow 1981) we found significant autocorrelation by language family, which was almost entirely accounted for by membership in the Bantu language family. We adjust for that autocorrelation in this study using a dichotomous variable for Bantu societies.³

Correlational Data

Table 2 presents Pearson's correlation among the variables. These correlations all support the model. Number of dry months, importance of domesticated animals, population density, and the plow all have negative and statistically significant correlations with the dependent variable. Root crops and cereal crops show the predicted directions of correlation with the dependent variable, and tree crops have a statistically significant negative correlation with the dependent variable ($p < .05$).

Among the independent variables, the plow, domesticated animals, population density, and cereal crops all have positive intercorrelations. Number of dry months has positive correlations with domesticated animals and cereal crops. Root crops have negative correlations with all four intensification variables—dry months, the plow, domesticated animals, and population density, as well as with cereal crops.

One pair of the independent variables, the plow and domesticated animals, are curvilinearly related. Almost all plow societies (27 out of 32 cases) are found in the middle ranges of dependence on domesticated animals (between 16% and 55% dependence on domesticated animals). There are, however, also 27 societies in these middle ranges that lack the plow, and the overall correlation between the two variables is not very high.

Table 2. Pearson's correlations among variables in the model.

	AgTot	Dry	Animals	Plow	PopDen	Root	Cereal	Tree	Bantu
AgTot	1.00	-.37	-.42	-.38	-.22	.35	-.21	-.14	.38
Dry		1.00	.39	.03	.07	-.31	.35	-.13	.02
Animals			1.00	.37	.14	-.29	.27	-.10	-.04
Plow				1.00	.42	-.24	.23	-.02	-.16
PopDen					1.00	-.17	.13	.06	.07
Root						1.00	-.77	-.19	.02
Cereal							1.00	-.45	.00
Tree								1.00	-.01

Table 3. Results of regression analyses.

Region	K	Dry	Animals	Plow	PopDen	Root ^a	Tree	Bantu	
West	14.3	-.25	-.87	-1.45	-.99	1.78	-	4.76	
R ² = .70	(2.9)	(.14)	(.32)	(1.07)	(.34)	(1.32)		(1.16)	
East	11.1	-.23	-1.04	-	-.55	5.24	N.A.	N.A.	
R ² = .67	(2.5)	(.14)	(.24)		(.26)	(2.92)			
Old World	11.8	-.22	-.97	-1.20	-.73	2.26	-	5.02	
R ² = .69	(2.7)	(.10)	(.20)	(.80)	(.22)	(1.14)		(.98)	
Oceania	22.7	N.A.	-	-5.37	.84	-	-4.08	N.A.	
R ² = .32	(3.4)			(2.33)	(.56)		(1.94)		
America	24.3	-.94	N.A.	N.A.	-	-	-4.45	N.A.	
R ² = .41	(3.4)	(.20)					(1.71)		
World	12.3	-.38	-.52	-2.13	-.24	2.40	-2.63	5.06	
R ² = .47	(3.3)	(.09)	(.19)	(.82)	(.17)	(1.26)	(.97)	(1.12)	
			p < .001	p < .005	p < .005	p < .10	p < .05	p < .005	p < .001

Note: Figures are unstandardized coefficients, with standard deviations in parentheses.

^a Old World root crops only. Root crops have no effect for Oceania or America.

Regressions

Results of the regression analyses are shown in Table 3. Here we report only those regression coefficients that are significant at the probability level of .10 or better. Variables with lower probability levels were deleted in computing each of the final equations. "N.A." in certain cells indicates that the particular variable does not occur frequently enough in that region to estimate the coefficient, for example, only one East Asian society with tree crops, no societies with very many dry months in Oceania, one American society with high dependence on domesticated animals, and only one American society with the plow. The average number of dry months is only 0.84 for Oceania, as contrasted with 4.00 for the rest of the world.

The model predicts a much higher proportion of the variance for the Old World than it does for Oceania and America. The R² value of .69 for the Old World is very high. The most likely explanation for the higher predictive power of the model within the Old World is that there are much higher degrees of agricultural intensification within the Old World, and our model is intended to predict the effects of intensification. There may be other causes of variability in the sexual division of labor among nonintensive systems that are not included in our model.

Across regions, the most consistently replicable variable is number of dry months. Regression coefficients for this variable are almost identical for the Eastern and Western regions of the Old World, and the variable also replicates with a sharper effect for America.

The importance of domesticated animals variable replicates well within the Old World, where the two regression coefficients are very similar. The nonreplication within Oceania is problematic, given the singular importance of pigs in much of Oceania. The most plausible conclusion from this result is that our hypothesized effect of care of domesticated animals is true only of the Old World complex of cattle, sheep, goats, camels, horses, and yaks, and that care of pigs has different consequences for the organization of family labor. There are two fairly obvious differences between pigs and the cattle-complex animals. First, pigs do not produce milk, wool, or hides, so their use does not require women to spend time processing these items. Second, pigs compete with

humans for food (Harris 1974), whereas the cattle-complex animals eat foods that are complementary to the human diet. Hence, pigs do not have the ecosystem links exemplified by such time-consuming women's tasks as gathering grass for fodder.⁴

Replication for the plow variable is weaker than for the domesticated animals or the dry months variables. The plow shows the strongest effect within Oceania, but its effect for the entire Old World is statistically weak, and it does not have a statistically significant effect within East Asia. We can conclude that the plow is a relatively weak predictor of female participation in agriculture once we have controlled for other variables. This is consistent with an earlier study (Burton and Reitz 1981). It seems likely that the plow has a direct effect on the division of labor only for tasks at the beginning of the agricultural sequence, such as soil preparation and planting.

Population density has significant effects on the division of labor only within the Old World, and that effect is stronger in the West than in the East. Within Oceania we find a reversal: a tendency for female participation in agriculture to increase with population density. Within the Americas, population density shows no relationship with the division of labor in agriculture. We will discuss later several possible reasons for the nonreplication of population density.

We do not find significant effects of cereal crops on the division of labor in agriculture. However, within the Old World, root crops predict higher female agricultural participation than either tree or cereal crops; and within the New World and the Pacific, tree crops predict lower female participation. The two coefficients for tree crops are almost identical. The finding concerning Old World root crops replicates our earlier study (White, Burton, and Dow 1981). A possible reason that root crops do not have the same effect in the Americas and Oceania as they do in the Old World is that these two regions have a different distribution of plant species. Manioc, in particular, takes considerable amounts of time for food processing, hence taking women's time away from agriculture.

We think there are good reasons to postulate a universally negative effect of tree crops on female agricultural participation. In fact, although there are few societies with tree crops in the Old World, regression coefficients for Old World tree crops are negative but not statistically significant. We hypothesize that the effect of tree crops is threefold. First, there is some danger involved in climbing trees for harvest. Second, trees are planted in relatively permanent orchards. The plantations provide a rich economic resource, and are an invitation to territorial fighting. Hence, the plantations would present some danger for female workers. Third, plantations are immovable, but most horticultural people change residence every few years. In a system with high dependence on tree crops but also a considerable amount of other subsistence cultivation, the plantations could be a considerable distance from the household. The factors of distance and danger would make tree cultivation a male task.

Putting the four regions together, we find that the world model predicts about half of the variance in female agricultural participation. Population density is barely significant at the .10 level; hence, its effect is weak. The other three intensification variables have very strong effects, as do tree crops. Root crops have a weaker effect, limited to the Old World. Finally, the Bantu language term has a very strong effect, showing that Bantu societies have, on average, five points more female participation in agriculture, all other factors being equal. This shows either that there are other factors affecting Bantu sexual division of labor that we have not yet identified or that we have measured an effect of historical tradition on the division of labor. In any case, the effect is quite striking, and is made more interesting by the fact that there is only one such autocorrelation effect within our sample. It is clear that household surveys and other kinds of ethnographic research on Bantu agriculture would add greatly to our understanding of the processes discussed in this paper (Lancaster 1981).

POPULATION DENSITY

Because of the theoretical importance of population density, we have explored some alternative hypotheses about its nonreplication within America and Oceania.

Our first hypothesis was that population density does not replicate within the American sample because there are few societies in that sample at the highest levels of density. If population density has its effect in the transition from medium to high density, then that effect would not be detected in the American sample. We tested this hypothesis by examining the effects of density within the Old World. Experiments with dichotomizing the population density variable and deleting high-density cases established that within the Old World, population density has a significant effect on female participation in agriculture even at very low range levels of density, such as the contrast between less than 1 person per square mile, and 1 to 25 persons per square mile.

A second hypothesis concerning density is that the reversal for the Oceanic density coefficient is due to the effects of an insular adaptation. We reasoned that small islands would have high population densities but that these measures would not be accurate indices of population pressure because of the extensive utilization of marine resources. To test this hypothesis, we coded the Oceanic societies for size of island (small versus large), and entered that variable as a dummy variable into the Oceanic regression equations. It had no effect either as a separate variable or in interaction with population density.

A third hypothesis concerning population density was that the weaker coefficient for density in East Asia is due to high female participation in intensive rice cultivation. Since intensive rice cultivation appears to be able to absorb more female labor than intensive cultivation of other cereal grains, it seemed plausible that there is less decline in female participation in rice cultivation with population density than would otherwise be expected. To test this hypothesis, we coded all of the societies in the East Asian region for presence of rice, importance of rice to the diet, and intensive cultivation of rice. None of these three variables had a significant effect when entered into the regression equation for East Asia.

It is no doubt true that wet rice agriculture has higher female participation than some other forms of intensive agriculture, but it appears to be associated with two other variables that predict relatively high female involvement—a short dry season and a relatively low degree of dependence on the cattle complex animals for subsistence. When we control for the effects of these variables, relatively high female participation in wet rice agriculture is understandable.

We are left, then, with a puzzle concerning the replicable effects of population density in the Old World and the nonreplication of the variable in the New World and Pacific. One possibility is that population density is not an accurate measure of population pressure. We think this is unlikely, since the variable predicts well for the Old World. We therefore explored two alternative explanations or possible misspecifications of the model. One, following Lomax (1977), is that warm climates allow women greater freedom to participate in agriculture. If warm temperatures also allow higher population densities, the inclusion of temperature in the model may bring out the independent effects of population density. We tested this hypothesis using Whiting's variable for mean temperature of the coldest month (Whiting, Sodergren, and Stigler 1982). In fact, temperature has the opposite effect on the division of labor to Lomax's prediction, once other factors are included in the model: all other things being equal, women have lower agricultural participation in societies with warmer winters. Furthermore, adding temperature to the model further weakens the effect of population density. The contribution of temperature to R^2 is trivial, with the figure for the world model increasing only from .47 to .48; so we have not included winter temperature in the final model.

As a second alternative, we explored the idea that population density is correlated in the Old World with one or more attributes of societal complexity that are the true cause of the observed effect, and that these levels of complexity do not occur in Oceania or the New World. In our model we have tried a large number of societal complexity variables from the cross-cultural data set, including fixity of residence, importance of hunting, importance of fishing, writing, presence of high gods, urbanization, technological specialization, money, political integration, social stratification, community size, levels of sovereignty, class stratification, and slavery. We have found none of them to have an effect on the model once the existing variables have been entered into the regression analysis.⁵ Slavery, which showed a significant effect for the African subsample (White, Burton, and Dow 1981), does not replicate across other regions, no doubt because of the historical uniqueness of the African slave trade.

The finding concerning slavery, however, leads us to suggest a speculative hypothesis concerning population density, based on male labor migration. Much of the Old World has been organized for several centuries into core societies that are merchant and industrial centers, and peripheral societies that provide raw materials and labor for these core societies (Wallerstein 1974). In many cases, the labor migration from periphery to core has mainly involved males, leaving a surplus of females at home in the periphery. As Levine (1970) and others have hypothesized, this would cause increased female subsistence production.⁶ Because the core societies tend to have higher population densities, this kind of skewed labor migration could explain the results for population density. Because the societies of Oceania and the Americas in our sample had been less touched by these kinds of phenomena at the time of ethnographic observation and for the most part are all societies peripheral to the world system, we would not expect the same effect of labor migration within those regions. If this argument is valid, then there is nothing intrinsic to population density that causes increased male participation in agriculture. This is not to deny the role of population density in causing certain processes of agricultural intensification, nor its importance in explaining other phenomena, such as the origin of market systems and the state, but merely to say that it may add nothing to the explanation of the agrarian division of labor, once we have accounted for the effects of specific intensification processes. This hypothesis, that male labor migration accounts for the apparent effect of population density on women's contribution to agriculture, is only speculative. Testing the hypothesis would require that the societies of the Standard Cross-Cultural Sample be coded for world systems linkages at the time of ethnographic observation, a task upon which we are now embarking.

SUMMARY AND CONCLUSIONS

We have developed a cultural ecological theory of the sexual division of labor in agriculture. This theory replicates well across several regions of the world and has strong explanatory power. Although we find support for Boserup's idea that there are linkages between agricultural intensification and the division of labor in agriculture, our theory is a major modification of Boserup's theory. We find that population density has only a weak effect on the sexual division of labor, and we introduce two new variables, number of dry months and the importance of domesticated animals to subsistence, that we find to be the strongest predictors of female participation in agriculture. Both have specific interpretations in terms of plausible time allocation processes. A long dry season causes seasonal time pressures, requiring males to increase their participation in agriculture. High dependence on domesticated animals increases the time women spend caring for animals and processing animals' products, resulting in decreased female participation in agriculture.

Two variables often discussed in the literature — the plow and crop type — are shown to be valid, but weaker, causes of variability in female participation in agriculture. With respect to crop type, we find that we must be specific about our definition of crops. No longer can we simply rely on the contrast between root crops and cereal crops. Rather, we find that tree crops have especially low female participation, and Old World root crops have especially high female participation. Hence we must differentiate between Old World root crops and New World root crops.

Another example of the need for careful specification of variables is seen in the differences between pigs and the cattle-complex animals. Unlike our general finding with respect to domesticated animals, a high degree of dependence on pigs for subsistence does not appear to cause decreased female participation in agriculture. We think this is the result of differences between pigs and cattle-complex animals with respect to feeding habits and the use of animal by-products.

We have identified two historical processes that appear to have affected the sexual division of labor in agriculture. First, we find that Bantu societies have consistently higher female participation in agriculture than would be predicted by our model. This effect seems to show the effect of cultural traditions on a group of societies that migrated throughout much of Africa in the recent past. Second, we have hypothesized that the rise of worldwide male labor migration during the past century may have increased female agricultural participation in the peripheral rural societies that are the source of much of this labor supply, and may account for our somewhat puzzling results with respect to population density. In spite of this evidence for historical processes, our overwhelming conclusion is the high predictability of the ecological model, and the failure of a large number of measures of cultural complexity and social stratification to explain the sexual division of labor.

NOTES

Acknowledgments. Research for this paper was supported by an NSF grant to the two authors. We wish to acknowledge the assistance of Candice Bradley, Malcolm M. Dow, and Karl Reitz, and the useful comments of Rae Blumberg, Frank Cancian, Carol Ember, Ellen Greenberger, Morgan MacLachlan, Pertti Pelto, Lilyan Brudner White, Beatrice Whiting, and John Whiting.

¹ The scale values for this code are very close to the natural logs of the population densities.

² We have interpolated missing data on some items provided we had data for that society on at least two of the three other items. This is done by computing the expected value for that item given the observed values on the other items and the statistical relationships among the four items.

³ We have tested the regional models for autocorrelation using Iterative Generalized Least Squares (Dow, Burton, White, and Reitz 1983), a new, computationally efficient procedure for network autocorrelation analysis (Dow, Burton, and White 1982; Dow, White, and Burton 1982; White, Burton, and Dow 1981). We found language family autocorrelation in two cases, Western Old World and America. As in our paper on Africa (White, Burton, and Dow 1981), we found that we could correct for the first instance of autocorrelation using a dummy variable for Bantu family membership. In the American case, the network autocorrelation analysis produced virtually identical results to those obtained from ordinary least squares.

⁴ It is easy to test the hypothesis that pigs have different effects than other domesticated animals, since we have a variable for type of animal from the codes on subsistence activities (Murdock and Morrow 1970). If we transform the domesticated animals variable to zero for the 30 cases that have pigs as the primary domesticated animal, the resulting variable has almost the same predictive power as the original variable. Hence we can conclude that the effect of domesticated animals is almost entirely due to animals other than pigs.

⁵ We also found no effect of date of ethnographic observation or altitude.

⁶ Since the Bantu societies of southern Africa have experienced very high rates of male labor migration since the late 19th century, this process could also explain all or part of our observed effect for Bantu language speakers.

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