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COMPETITION, COOPERATION, AND CONFLICT: AGRICULTURAL PRODUCTION AND COMMUNITY CATCHMENTS IN THE CENTRAL MESA VERDE REGION

MARK D. VARIEN
Crow Canyon Archaeological Center
23390 C. R. K
Cortez, CO 81321

CARLA R. VAN WEST
Statistical Research, Inc.
6099 E. Speedway Blvd.
Tucson, Arizona 85712

G. STUART PATTERSON
33 Cuesta Rd.
Santa Fe, NM 87505

ABSTRACT

Using geographical information system (GIS) analyses, we integrate archaeological and environmental data in order to examine the changing social landscape in a portion of the central Mesa Verde region between A.D. 1050 and 1290. We identify the largest and most persistent communities in this area and define their agricultural catchments. These catchments overlapped increasingly through time, creating a social landscape in which people competed increasingly for agricultural land. We quantify agricultural production in these community catchments by year and find that on average, productivity decreased through time. We use these results to evaluate how catchment overlap affected the productive potential of each community and whether the increased competition for land stimulated cooperation and/or conflict among communities.

RESUMEN

Por el usaje de anallsis de GIS, integramos los datos arqueologicos y del medio ambiente para examinar el paisaje social en cambio en una parte de la región central Mesa Verde entre de D.C. 1000 y 1300. Identificamos a las comunidades más grandes y perseverante en este area y definamos a sus captaciónes agrlcolas. Estas captaciónes, se superpusieron por tiempo, cada vez mas, creando a una paisaje sociál en cual la gente compitió cada vez más para tierra agricola. Nosotros cuantificamos a la produccion agricola en estas capaciónes de comunidad. Por el año y hallamos que en promedio, productividad se bajó por tiempo. Usamos a estos resultados para evaluar como el superpone de las captaciónes afectó a la productiva potenciál de cada comunidad y si la competlción aumentada por la tierra estimuló a la cooperación y/o conflicto entre las comunidades.

The social landscape of the Mesa Verde region can be better understood by combining what we know about agricultural production in the area with our current knowledge of ancient settlement there. In this paper, we assess agricultural production in a portion of the central Mesa Verde region, documenting variation in production across space and through time. We then evaluate these estimates of agricultural production in terms of the number of people living in our study area and the location of their settlements.

Van West (1994) analyzed agricultural production for a portion of the central Mesa Verde region. In order to evaluate how agricultural production affected the social landscape, we combine her study with Varien's (1999) reconstruction of community catchments and with estimates of community population size (Mahoney et al., this issue). These combined analyses allow us to reconstruct the productivity of community catchments in a portion of the central Mesa Verde region between A.D. 1050 and 1300. The changing agricultural production in community catchments is used to evaluate the degree to which competition over agricultural land increased through time and to assess how elevated competition might have stimulated both cooperation and conflict among neighboring communities.

We find that a growing number of communities crowded into the study area through time, and most of them grew in population. The increasing number of communities resulted in an overlap of their primary catchments, shrinking those catchments and thereby heightening the potential for competition over agricultural land. Moreover, average productivity per hectare in these catchments decreased through time, because some communities began to use less productive land. Finally, the populations of these communities grew to the point at which most of the best land was likely in production or lying fallow, intensifying competition over the best land within and among communities.

KEY TERMS

We begin by clarifying how we use the terms *competition* and *community.* We use *competition* to focus on the relationship between people and their access to arable land. Van West's analysis of arable soils and agricultural production demonstrated that the quality of arable land was variable, but the amount of the best land was relatively fixed. The ancient inhabitants of the Mesa Verde region had to share agricultural land, and because this resource was variable and limited, we assume that, to some degree, people competed over access to the best agricultural land. The level of competition over agricultural land was presumably negligible under conditions of low population density, abundant high-quality arable land, and frequent residential movement in which groups relocated to fertile new land away from their abandoned fields. The level of competition over the best agricultural land presumably intensified as population density increased and the frequency and distance of residential moves decreased (Varien 1999). Competition might also have escalated as people improved the land through labor investments—for example, by clearing fields and constructing facilities associated with those fields. One of the primary goals of our research is to assess the degree to which competition over the best arable land increased through time.

Increasing competition over arable land could have resulted in a variety of behaviors. Heightened competition might have increased the potential for disputes over access to land, disputes that could have escalated into conflict or violence. But rising competition might also have resulted in the development of increasingly formal systems of land tenure (Adler 1996; Netting 1976:137). Land tenure systems are attempts to resolve the problem of sharing natural resources—including agricultural land—through cooperation rather than conflict. In most cases, land tenure systems are exclusionary; they specify who cannot use a resource (Adler 1996). It is therefore not surprising that ethnographic studies of land tenure systems show that conflict over land and cooperation in its use are not mutually exclusive. Instead, the potential for conflict and attempts to resolve conflict through mechanisms that promote cooperation typically exist simultaneously (Bauer 1987; Bohannan 1963; McCay and Acheson 1987). Indeed, land tenure rules become more complex as resource scarcity increases, and the growing complexity of land tenure rules means that they are more likely to be contested and difficult to resolve. Finally, systems of land tenure do not ensure that everyone has access to equal amounts of the best land. This, too, results in challenges to the principles that govern land tenure systems (Ostrom 1987).

Adler (1996) has discussed how resource access systems are multidimensional and layered in any society. That is, access rights can rest with individuals, households, larger corporate groups, and even an entire community, depending upon the particular resource involved (e.g., firewood vs. agricultural land). The community is typically the largest group that defines exclusionary access to a particular resource. Thus, communities play an important role in land tenure systems in nonindustrial agrarian societies (Adler 1996; Brush and Turner 1987). Within communities, land tenure systems allow individuals, households, and larger corporate groups to negotiate their access to resources vis-à-vis each other. Collectively, land tenure enables members of a community to protect their land use rights from claims by members of other communities.

In this study, we examine agricultural production and competition over land at the social scale of residential communities. We define a *residential community* as a cluster of many households whose members lived close to one another, had regular face-to-face interaction, and shared the use of local social and natural resources (Adler 1994; Adler and Varien 1994; Varien 1999). Regular face-to-face interaction would have limited the geographic size of a residential community. On the basis of a variety of cross-cultural and archaeological studies, we assume that residential communities occupied areas with radii of approximately 2 km, adjusted for topography (Varien 1999:153–154).

In order to examine the distribution of communities in the Mesa Verde region, we use the locations of known community centers. Community centers are dense concentrations of residential settlement; they typically include a single building or tight cluster of buildings that contains more than 50 structures. They are often, but not always, associated with public architecture. An inventory of community centers in the Mesa Verde region was initiated in 1990 by archaeologists at the Crow Canyon Archaeological Center and their colleagues who work in the region (Lipe 1995; Varien et al. 1996). The effort to identify centers continues to the present; we currently know of more than 130 centers in southwestern Colorado and southeastern Utah that were occupied between A.D. 900 and 1300 (Varien 1999).

Where surveys have been conducted, each of these community centers has been found to be associated with a larger settlement cluster composed of contemporaneously occupied small residential sites (Adler 1992; Fetterman and Honeycutt 1987; Neily 1983; Rohn 1977). Analyses of some centers suggest that they were places of economic and political activities that did not occur at other sites in the community (Adler 1994; Bradley 1988, 1993; Driver 1996; Martin 1936; Thompson 1993, 1994). The role of each of these centers within its residential community and in the regional social landscape, however, remains an issue that deserves additional empirical research. For the purposes of this study, it is enough to know that each community center indicates the location of a residential community.

THE DATA

In the analyses that follow, we use several distinct data sets. The first is Van West's (1994) analysis of agricultural production. The second is the locations of Mesa Verde region community centers found in Van West's study area (Varien et al. 1996; Varien 1999). The third is a catchment analysis of these community centers conducted by Varien (1999). Details of each of these studies are reported elsewhere, so we present only a brief summary here.

Agricultural Production

Van West (1994) reconstructed potential agricultural production in a 1,736-km² area in the central Mesa Verde region. First, she determined and recorded the predominant soil type in each 4-ha unit in the study area. Second, she recorded data on soil quality, soil depth, available water capacity, natural plant productivity, and agricultural characteristics for each soil type. Third, she associated the elevation of each 4-ha cell with the precipitation and temperature records of an appropriate and proximate weather station within or adjacent to the study area. Fourth, she used the modern climate and soil data to calculate Palmer Drought Severity Index values, or PDSIs, which are temporally sensitive indicators of soil moisture commonly used to model the success of dry-farming agriculture. Like tree-ring width data, PDSIs integrate the effects of precipitation and temperature on available stores of soil moisture. In Van West's study, PDSIs were correlated with tree-ring width index data for the same set of years. This produced a calibration, or transfer function, that was applied to the full length of the tree-ring series, A.D. 901 to 1970. In this way, annual reconstructions of PDSI were produced, one for every combination of soil type and weather station–specific elevational band.

Fifth, Van West used the long-term PDSI reconstructions to assign annually specific PDSI values to each 4-ha cell. Each value represented locally specific soil moisture conditions as they existed on July 1 of each year from A.D. 901 to 1970. Sixth, she re-expressed the compiled annual PDSI values as potential maize yields for every year in the time series. This was accomplished through regression analysis and estimation procedures following a study of the relationship of natural plant productivity and historic crop yields on specific soils of the region. The end products of these geographical information system (GIS)–coordinated steps were 400 annual maps (A.D. 901–1300) depicting the distribution of climatically conditioned yield values for potential maize production for each 4-ha cell in the study area, as well as a tabular summary of yearly yield estimates for the four-century period.

Community Centers

The known Mesa Verde region community centers that date between A.D. 1050 and 1300 are illustrated in Figure 1. They lie in an arc that stretches from Mesa Verde on the southeast to Cedar Mesa on the west; the largest and most densely clustered centers are found in the area between Montezuma and McElmo Creeks. The location of Van West's study area for agricultural production is roughly equivalent to the area where community centers are most numerous (Figure 1).

Community centers have been dated to one of three time periods: A.D. 1050–1150, 1150–1225, and 1225–1290 (Varien 1999; Varien et al. 1996). When available, tree-ring dates were used to make the temporal assignments of community centers (32 sites; 24% of the total). The types of pottery, architecture, and site layouts at the tree-ring-dated centers were used as benchmarks for assigning centers without tree-ring dates to a time period (Varien 1999:141–142). This chronological study documents changes in community center form according to what has been termed the "community center succession model." This model is evaluated in greater detail, and a variety of centers are illustrated, in Lipe and Ortman (this issue) and Ortman et al. (this issue).

For the A.D. 1050–1150 period, there were 16 community centers in Van West's study area. These centers were typically located in upland settings on the deep, eolian soils that were the preferred soils for dry farming in the historic period. They were often situated on a high point that offered a commanding view of the

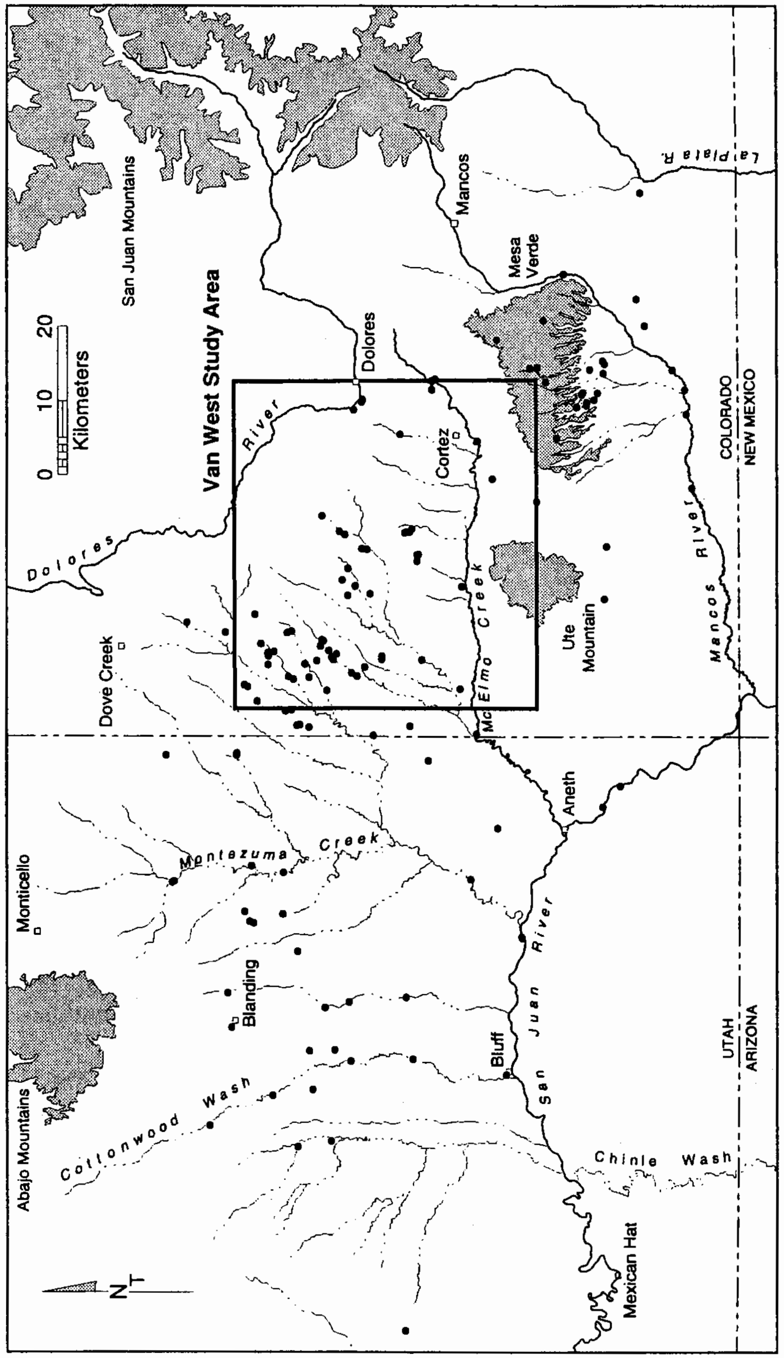

Figure 1. The Mesa Verde region showing all community centers in southwestern Colorado, southeastern Utah, and the Van West study area. Courtesy of Crow Canyon Archaeological Center.

surrounding area. The centers were associated with small unit pueblos that typically consisted of a single kiva, a roomblock, and an associated midden (Lipe 1989:54). Together, the centers and the associated unit pueblos composed dispersed communities (Adler and Varien 1994). The community centers were small relative to centers in subsequent periods, but they were often two-story buildings that were considerably larger than the other residential sites in the community. Several of these sites have been excavated and classified as Chacoan outliers because they exhibited architectural similarities to great houses in Chaco Canyon (Bradley 1988; Hallasi 1979; Martin 1936; Thompson 1994). The known public architecture at these centers included an associated great kiva at each of seven centers and ancient roads associated with two. There may have been a multiple-walled (biwall or triwall) structure at one center.

For the A.D. 1150–1225 period, there were 19 community centers. These, too, were located in the uplands on the deep eolian soils. The form of the center changed such that these centers were multiple-roomblock sites in which larger roomblocks clustered together (see Lipe and Ortman, this issue, and Ortman et al., this issue). In some cases, a single roomblock in the cluster was larger than the others; these may have been analogous to what have been termed post-Chacoan great houses in the Zuni region (Kintigh 1994; Kintigh et al. 1996). These community centers continued to be associated with smaller residential sites, and the overall community remained dispersed (Adler and Varien 1994). In terms of known public architecture, six centers may have had associated great kivas, two had an associated ancient road, and three had possible multiple-walled structures.

Twenty-eight community centers in the study area dated to the final period, A.D. 1225–1290. These were all compact villages typically located in canyon settings. Although most community members lived in these villages, smaller residential sites were associated with them as well (Mahoney et al., this issue). These two changes—the move from the uplands to the canyons and the formation of large, compact villages—represent a dramatic change in the social landscape in the Mesa Verde region, one that may have presaged the even more dramatic migration from the region that was completed by A.D. 1300 (Duff and Wilshusen, this issue). These changes in settlement pattern were great, but Varien has shown that only short distances separated these compact villages from the community centers of the previous period (Varien 1999:188). He argues that the short distance between community centers in successive periods is evidence for continuity in community settlement despite the changes in community form (Varien 1999:184–188, 202–207). There were three known great kivas associated with these villages and four possible multiple-walled structures.

Community Center Catchments

Varien (1999) analyzed changes in the Mesa Verde region social landscape by constructing catchments around each of the community centers. The physiography of the Mesa Verde region is characterized by nearly level uplands dissected by steep canyons, and Varien argues that the corresponding changes in elevation would have affected foot travel and interaction among neighboring communities. He incorporated physiography into his analysis of community catchments by using GIS software to transform the elevational data in a digital elevation model into a friction surface in which every 30-by-30-m pixel was assigned a value for the energy required to walk across that surface. He then constructed catchments that reflected the cost of walking outward from each community center (for a more detailed explanation of this analytical procedure, see Varien 1997:325–327; 1999:150–151).

The analyses that follow focus on the 2- and 7-km catchments, adjusted for topography, around each community center. A 2-km radius was selected as a reasonable estimate for the size of a residential community in which people could regularly interact on a face-to-face basis and for the size of the area in which they practiced their most intensive agriculture. Cross-cultural studies support the interpretation that most intensively cultivated fields lie within a 2-km radius of the primary residence (Arnold 1985:34; Stone 1991, 1992). In addition, Stone examined the distance that Kofyar farmers travel to take part in agricultural work groups and found that 2 km was an upper limit (Stone 1991:347, 1992:166). Finally, archaeological studies in the Mesa Verde region further support the use of a 2-km threshold for the size of the most intensively used agricultural catchment and for the size of a residential community. In the Dolores River valley, the maximum one-way distance between habitations and fields, averaged for all households, was 1.7 km in the A.D. 880–920 period (Kohler et al. 1986:536). In the Sand Canyon locality, settlement clusters associated with public architecture have radii of approximately 2 km (Adler 1994; Adler and Varien 1994). Cross-cultural studies indicate that a 7-km catchment is a reasonable estimate for the area in which more extensive agriculture was practiced and which was regularly visited to obtain raw materials for pottery manufacture and other tasks (Arnold 1985:34; Bradfield 1971:21).

THE ANALYSES

Figures 2, 3, and 4 illustrate the community centers and their adjusted 2- and 7-km catchments for each of the three periods examined. These figures show changes in the social landscape in the study area between A.D. 1050 and 1290. Increasing numbers of communities clustered into a smaller portion of the study area—the portion that provided the most immediate access to both canyon and upland environments.

Community centers dating between A.D. 1050 and 1150 were relatively evenly spaced, with little overlap in their 2- and 7-km catchments. The exceptions were three areas in which three large buildings clustered close together: the Lakeview

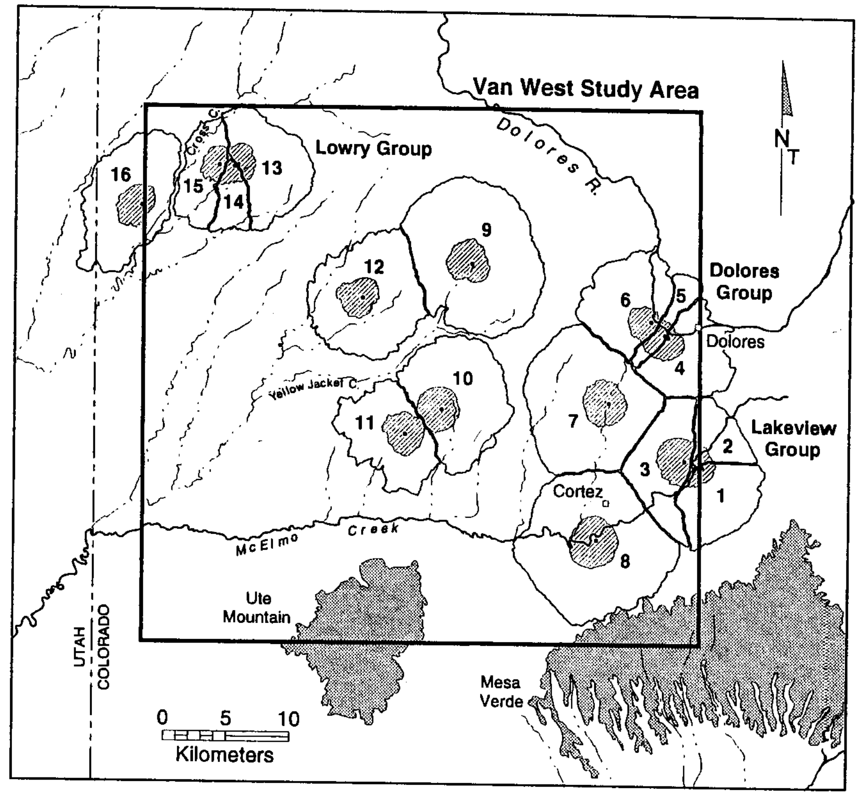

Figure 2. Community catchments in the Van West study area, A.D. 1050 to 1150. The location of the community center is represented by the dot, the hatched polygon is the 2-km catchment, and the open polygon is the 7-km catchment. The community centers are as follows: 1. Wallace, 2. Haynie, 3. Ida Jean, 4. Emerson, 5. Reservoir, 6. Escalante, 7. Hartman Draw, 8. Mitchell Springs, 9. Yellow Jacket, 10. Goodman Point, 11. Casa Negra, 12. Albert Porter, 13. North Lowry, 14. Lowry, 15. Casa de Valle, and 16. Upper Squaw Mesa. Courtesy of Crow Canyon Archaeological Center.

group, composed of the Wallace, Haynie, and Ida Jean community centers; the Dolores group, composed of Reservoir, Emerson, and Escalante; and the Lowry group, composed of Lowry, North Lowry, and Casa de Valle (Varien 1999:167, 172–173). We treat each of these multiple-center clusters as a single area in the catchment analyses that follow.

The distribution of community centers dating between A.D. 1150 and 1225 showed two changes. Community centers located on the eastern edge of the study area in the earlier period were abandoned, and there was increased clustering of community centers in the western portion of the study area, resulting in greater overlap of their catchments. These trends became even more pronounced between

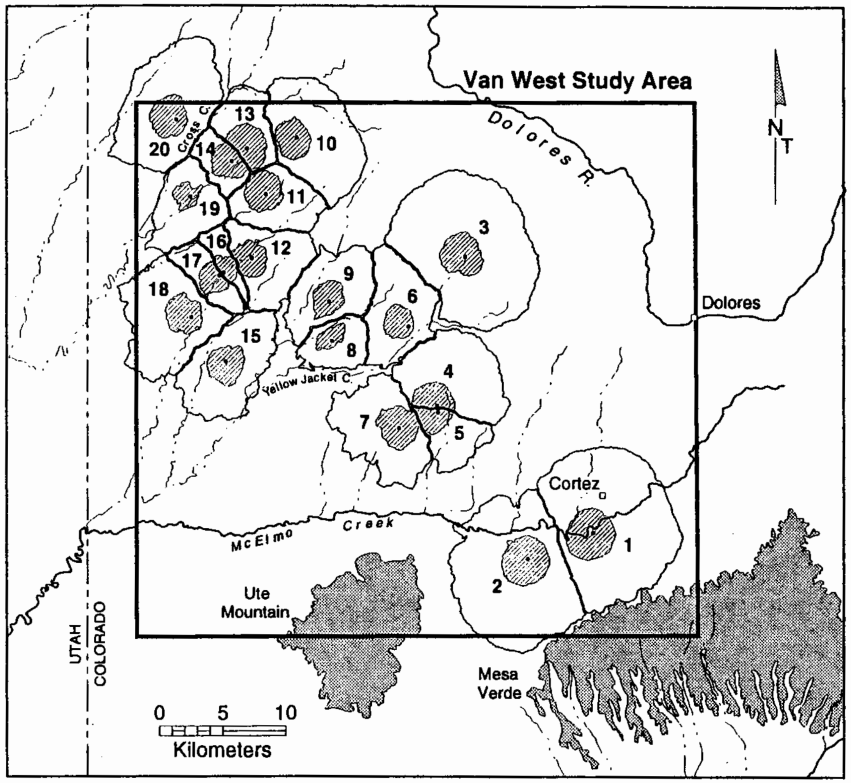

Figure 3. Community catchments in the Van West study area, A.D. 1150 to 1225. The location of the community center is represented by the dot, the hatched polygon is the 2-km catchment, and the open polygon is the 7-km catchment. The community centers are as follows: 1. Mitchell Springs, 2. Mud Springs, 3. Yellow Jacket, 4. Shields, 5. Goodman Point Great Kiva, 6. Griffey, 7. Casa Negra, 8. Rich's, 9. Bass, 10. Lancaster, 11. Herren, 12. Hovenweep Mesa Top, 13. Finley/Charnel/Ray, 14. Pigg, 15. Mockingbird Mesa Top, 16. Kristie's, 17. Carol's, 18. Kearn's, 19. Cow Canyon, and 20. Brewer Mesa Top. Courtesy of Crow Canyon Archaeological Center.

1225 and 1290. The increased clustering over time enhanced the potential for competition over resources in this area.

But the question remains: did community catchments overlap until they became too small to meet the needs of the community, or were these catchments so productive that competition for resources was negligible, both within an individual community and among neighboring communities? We examine this question by measuring agricultural production in catchments surrounding communities located in the central Mesa Verde region.

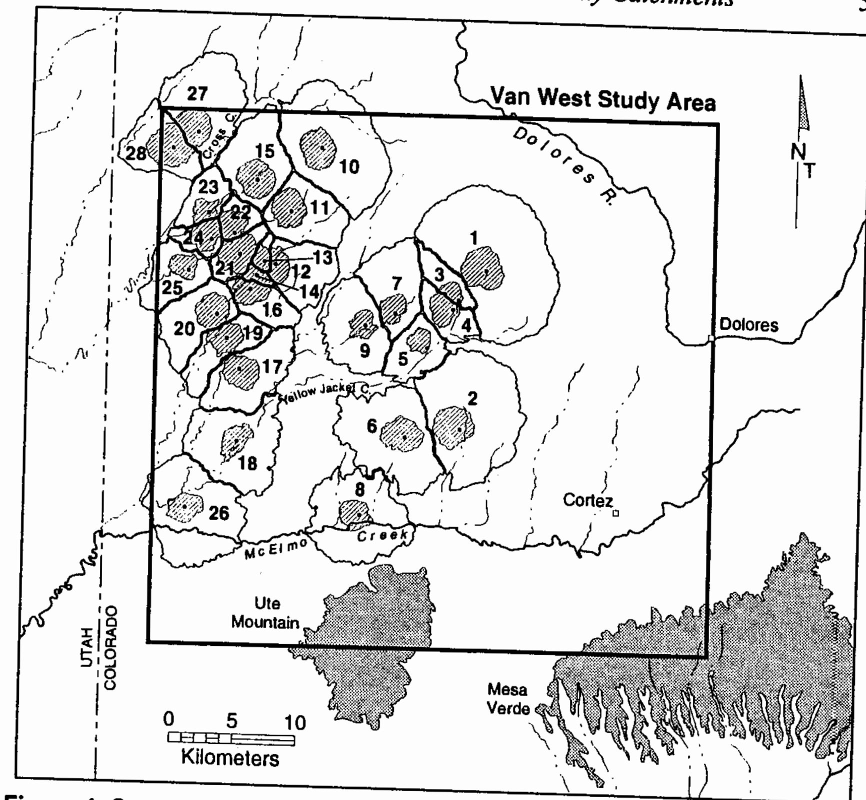

Figure 4. Community catchments in the Van West study area, A.D. 1225 to 1290. The location of the community center is represented by the dot, the hatched polygon is the 2-km catchment, and the open polygon is the 7-km catchment. The community centers are as follows: 1. Yellow Jacket, 2. Goodman Point Pueblo, 3. Rohn 84, 4. Stevenson, 5. Easter, 6. Sand Canyon Pueblo, 7. Rohn 150, 8. Castle Rock, 9. Woods Canyon, 10. Lancaster/Pharo, 11. Beartooth, 12. Gardner, 13. Miller, 14. McVicker, 15. Little Cow Canyon, 16. Thompson, 17. Seven Towers, 18. Yellow Jacket Floodplain, 19. Hibbett's, 20. Big Spring, 21. Fuller, 22. Ruin Canyon, 23. Cottonwood, 24. Cow Mesa 40, 25. Lew Matis Village, 26. Cannonball, 27. Brewer Canyon, and 28. Hampton. Courtesy of Crow Canyon Archaeological Center.

Catchment Size

Through time, there was increasing overlap in the catchments associated with each center as more centers clustered into a smaller area. This effectively reduced the catchment area associated exclusively with each center. Using the friction surface, we determined the boundary between each set of overlapping catchments (see Figures 2, 3, and 4) in order to isolate the portion of the catchment that was exclusively associated with each center. We used these boundaries to calculate the size of each catchment, thereby illustrating how catchment size was reduced by increasing catchment overlap.

These studies of catchment overlap assume that the centers in each period were occupied at the same time and for the full duration of the period. We cannot be certain that this was true for every center, but tree-ring dates, where available, and pottery assemblages do support the interpretation of contemporaneous rather than sequential occupation. The depths of midden deposits and the characteristics of pottery assemblages also indicate that these centers had lengthy occupation spans and were among the longest-lived sites in the region (Ortman et al., this issue). Nor can we be absolutely certain about which specific parcels of land were used by particular communities, though the analysis of community catchments makes sense from the standpoint of efficiency.

Figure 5 shows the means and standard deviations for the sizes of the adjusted 2- and 7-km catchments in each period. In order to understand these data, it is important to recognize that *2-km catchment* and *7-km catchment* are simply labels for these two categories of catchments, and not real measurements. The catchments do not have fixed areas; instead, they vary in size as a result of two factors. First, we created the catchments using the friction surface, so that they represent not a set area but rather the 2- and 7-km walking distances outward from every center. Second, catchment size is reduced by catchment overlap. We used the friction surface to determine the boundaries between catchments that overlapped (see Figures 2–4), and then we calculated the area of the portion of each catchment that was exclusively associated with each center.

For the 2-km catchments, average catchment size decreased in each period such that catchments in the initial period were approximately twice as large as catchments in the final period (Figure 5). The same trend characterized the 7-km catchments: in the initial period, they were almost three times the size of catchments in the final period. These analyses show how catchments became smaller as community centers became more numerous and clustered, resulting in greater potential for competition over resources.

Catchment Productivity

In order to examine catchment productivity in greater detail, we calculated average agricultural production for each time period, first for the 2-km catchments and then for the 7-km catchments minus the 2-km areas. Figure 6 shows these productivity values for the 2-km and 7-km catchments for all three periods. Average production is the center of the circle, and the size of the circle illustrates the standard deviation. The black circles show the productivity of the 2-km catchments, and the white circles show values for the 7-km catchments.

Figure 6 illustrates two important patterns. The first is a change through time: there was a steady decline in the average production of the community center

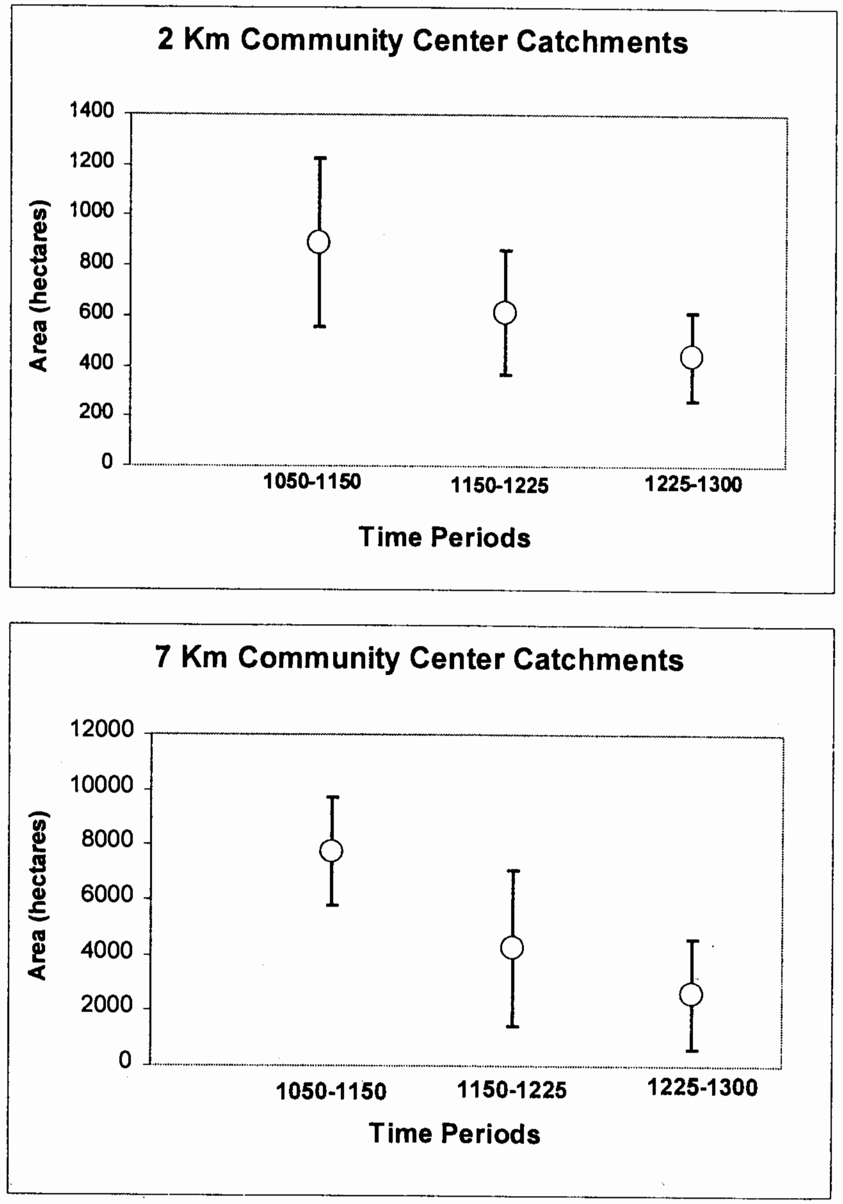

Figure 5. Mean and standard deviation for the size of the 2-km (top) and 7-km (bottom) catchment areas through time.

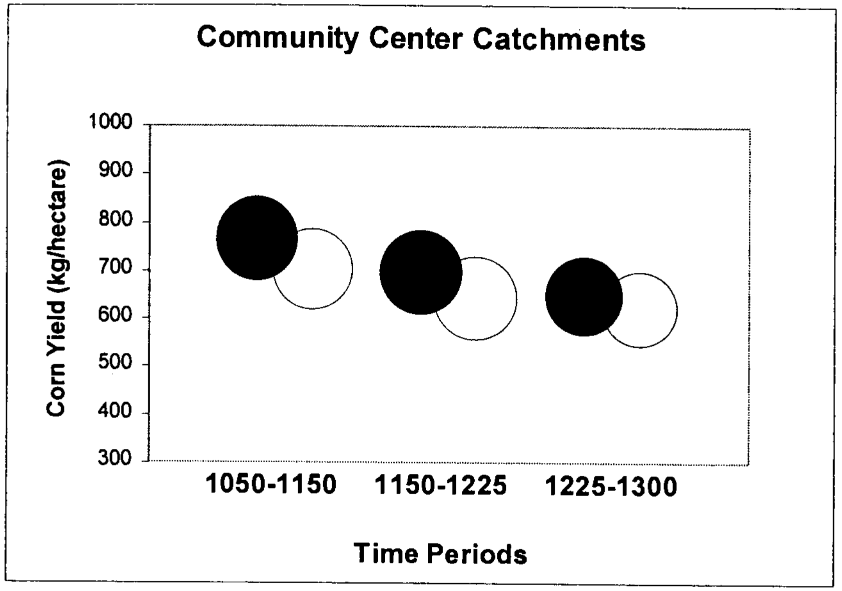

Figure 6. Bubble plots showing average catchment productivity through time.

catchments. This was true for both the 2- and the 7-km catchments. We believe that this was largely a result of the increase in the number of community centers through time. New communities settled in areas of slightly lower productivity, reducing the overall mean for each period.

The second pattern is that within each period, the 2-km catchments were always more productive than the 7-km catchments. This trend indicates that community centers in each period were located on the most productive land in their local environment. Both trends suggest that the inhabitants of these communities were aware of even subtle differences in the productive capacity of the landscape and that there may have been competition for the most productive locales.

Catchment Productivity and Community Size

In order to fully assess the degree of competition over agricultural land, we need to examine the population size of these communities. We do this by focusing on three intensively surveyed areas and four residential communities: the Lowry area community, the Mockingbird Mesa area community, and the Sand Canyon area, where the Sand Canyon and Goodman Point communities were located. We examine whether the 2-km catchments surrounding these communities would have provided sufficient yields to feed these groups. The estimates for community size are those calculated by Mahoney and others (this issue). These authors standardized the data from intensive surveys in each of these areas and determined the number and sizes of residential sites in each time period. They combined these

data with estimates of the occupation span for residential sites in order to calculate momentary population estimates for each community in each time period. (Mahoney et al., this issue, Table 3). We assume that each person needed 160 kg of corn each year to survive, and that farmers put enough land into production to provide one year's worth of corn for consumption and two years' worth for storage (or 480 kg of corn per person).

Given these assumptions, the first analysis examines how much of the *total* 2-km catchment would have had to be under production in order to feed the inhabitants of each community. As Figure 7 shows, that amount was quite low, ranging from approximately 2 to 8 percent in the Early Pueblo II period (approximately A.D. 1000) and rising to approximately 27 to 48 percent in the final period. This estimate implies that a large portion of the catchment might not have been cleared for agricultural production and would have been available for other critical resources, such as timber for construction and fuel.

These figures seem to indicate relatively low levels of competition for agricultural land. To examine this question further, we asked how much of the 2-km catchment would have been in production if people had farmed only the *best* agricultural lands within each catchment. We further assumed that people would not have relied on getting the mean production each year, so we used a production value that was one standard deviation below the mean. Using these assumptions, the amount of the best agricultural land in production was still relatively small—approximately 3 to 16 percent—in the Early Pueblo II period, when communities were also relatively small. The percentage rose considerably by the final period, when between approximately 43 and 79 percent of the best land would have been in production (Figure 8). Competition for the best agricultural land likely increased in this final period, especially considering that these estimates do not include the need to occasionally fallow agricultural fields.

Beaglehole (1937:36) and Forde (1931:391) described Hopi fields as being in nearly continuous production. When fallowing did occur, it was limited to a brief period of approximately two years. It is likely that there were some fallow fields in the ancient farming communities of the Mesa Verde region, and the question here is whether the ownership of these fallow fields was contested. According to our estimates for the amount of the best land in production, a large majority of such land in the 2-km catchments would have been left uncleared or fallow in the earliest period. The best land might have been so abundant during this period that there were no ownership rules governing fallow fields. By the final period, this situation had changed; approximately half of the best land would have been under production. If producers wanted to own enough land to have as much lying fallow as they had in production, then virtually all of the best land would have been claimed. Thus, there might have been competition over ownership of fallow land at the time of peak population, and land tenure systems might have developed to the point that they specified the ownership of this land.

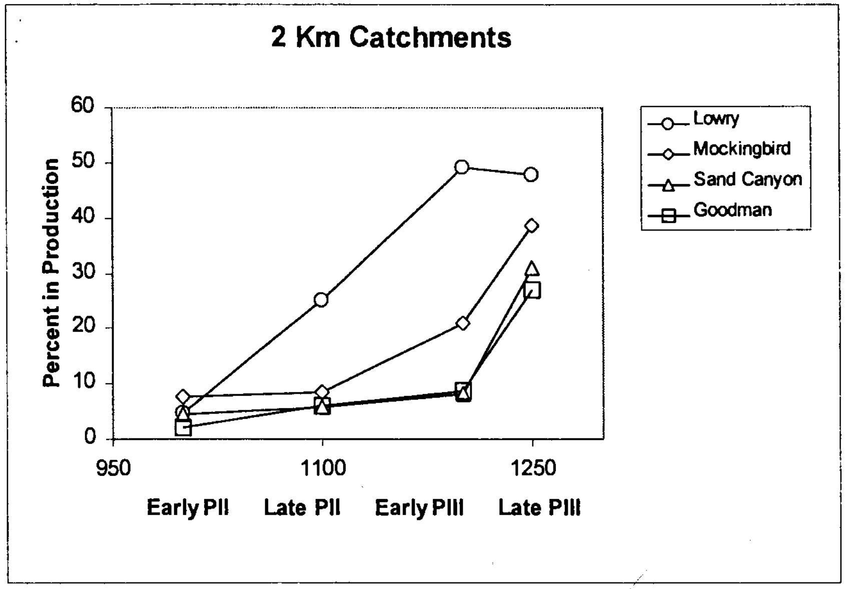

Figure 7. The amount of the total 2-km catchment in production through time.

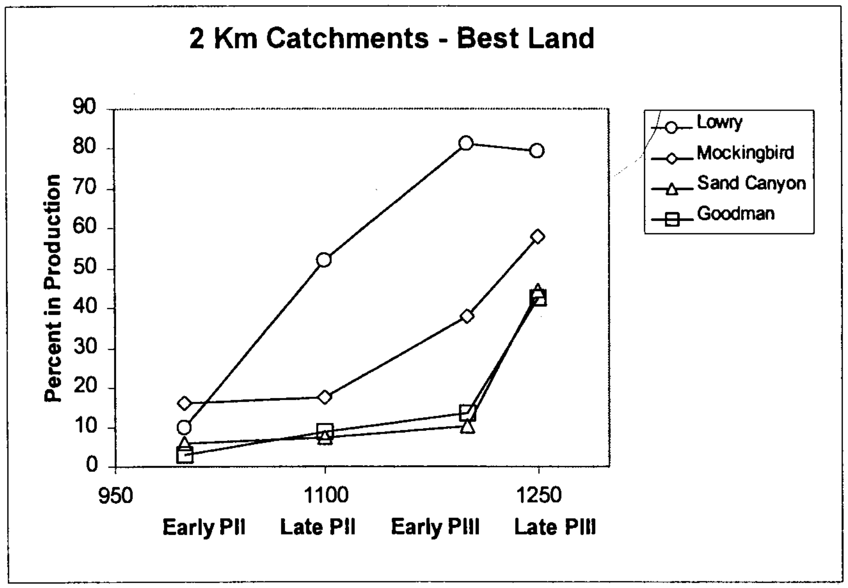

Figure 8. The amount of the best land within the 2-km catchment in production through time.

CONCLUSION

Analyses such as these are always at the mercy of the assumptions used in the calculations. Although they are not perfect, we are fortunate to have some of the best data ever assembled to make such calculations. To further check the accuracy of our estimates for agricultural production and the assumptions used in our calculations, we used these data to calculate the amount of land a family would have had in production and then compared this figure with an ethnographic estimate of the amount of land farmed by a Hopi household. Judging from our calculations, a family of seven in the Mesa Verde region would have had an average of 3.7 ha, or about 9 ac, in production. Beaglehole reported the following with regard to the amount of land in production at Hopi: "Besides individual owned land a household of seven or eight persons will usually cultivate the equivalent of about seven acres of land, most of this with corn, a minor amount of beans, squash, melons and garden products" (1937:37). The similarity of these figures indicates that our estimates of agricultural production and the assumptions we used are approximately correct. If anything, this comparison suggests that our estimates of the amount of land in production in the Mesa Verde region are slightly high.

In light of this observation, several of the patterns we have identified will likely withstand future refinements in the data and assumptions used for such calculations. First, farmers probably focused on only the best soils for their farms, since there was always more than enough of this land to meet the needs of the community. Second, the use of only the best soils meant that portions of the 2-km catchments were never cleared for agricultural production, leaving those areas to be used for other resources. This point is supported by macrobotanical data from the Sand Canyon locality, which suggests that intact pinyon-juniper woodland was located close to sites even in the final decades of the region's occupation (Adams and Bowyer n.d.). Third, the amount of the best agricultural land in production did increase in many communities, and it rose to the point where there might have been competition for this important resource.

The question remains as to whether this competition stimulated conflict or cooperation; the answer may be that it stimulated both. Within communities, competition over the best land might have increased to the point that more formal land tenure systems were needed to specify the ownership of both the fields in production and those lying fallow. Land tenure might have been contested within communities, but it seems unlikely that violent conflict was a routine way to resolve these disputes, because there was always enough of the best agricultural land to go around.

Competition between communities might have been more significant. Land tenure not only specifies ownership within communities but also seeks to protect the land use rights of community members against claims made by outsiders. As the region filled with more people and competition over the best land increased, communities might have had to increasingly defend their territory and land use rights against claims by neighboring communities (Stone and Downum 1999). This competition might have created a paradox for Mesa Verde region communities. Larger communities would have been better able to defend their territories, and communities in the Mesa Verde region might actually have tried to recruit members for this reason. But it would have been counterproductive for communities to become so large that there were internal disputes over land ownership that could not be resolved through land tenure rules and cooperative sharing. Some communities in the Mesa Verde region appear to have come close to this threshold during the period of peak population.

That communities continued to crowd into the central Mesa Verde region over time suggests that they did succeed in meeting their productive needs and that they developed more formal mechanisms for cooperation. However, increased competition for the best agricultural land, especially competition between communities, may have resulted in violent conflict during the period of peak population. Violence such as that documented at Castle Rock Pueblo (Kuckelman et al., this issue; Lightfoot and Kuckelman n.d.) might have been produced in part by this heightened level of competition. The tension between the increasing potential for conflict and the development of social strategies to reduce that conflict might have been a defining characteristic of the last century of occupation in the Mesa Verde region.

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