Chapter 28

Surveys of People and Place

Peter H. Dana

This chapter uses examples from recent participatory mapping projects in Central America to illustrate the dynamic interplay between conceptions of people and place and the methods used to survey them. Surveyors, census takers, and map makers have long been characterized as agents of power. J. B. Harley suggested in a workshop twenty years ago that "as much as guns and warships, maps have been the weapons of imperialism" and that "surveyors marched alongside soldiers, initially mapping for reconnaissance, then for general information, and eventually as a tool of pacification, civilization, and exploitation of the defined colonies" (Harley 1988, p. 282). More than a dozen years ago Benedict Anderson reminded us, in the context of colonial nation-building, that the map and the census "shaped the grammar that would in due course make possible 'Burma' and 'Burmese,' 'Indonesia' and 'Indonesian'" (Anderson 1991, p. 185). Mark Monmonier coupled the idea that "the map is the perfect symbol of the state" with his caustically worded assertion that "maps made it easy for European states to carve up Africa and other heathen lands, to lay claim to land and resources, and to ignore existing social and political structures" (Monmonier 1991, p. 90). In the past few years individuals, communities, and special interest groups of all kinds have accepted Denis Wood's proposition that "the interest the map serves can be yours" (Wood 1992, p. 182). In 1995 Peter Poole reported on 60 projects around the world applying geomatics to bolster land claims, manage resources, gather traditional knowledge, and mobilize indigenous groups (Poole 1995). Since then many more projects have been undertaken with varying levels of success. The past decade has seen an increasing awareness of the influence that use and misuse of spatial data can have on the welfare of people and place (Chapin, Lamb, and Threlkeld 2005). Phrases such as *counter-mapping*, *participatory mapping*, *community participation in Geographic Information Systems (GIS)*, and *public participation in GIS* are now commonplace in the field and in the literature of the social sciences, representing a wide range of activities that have begun to restore the balance of power in the realm of mapping, surveying, and census taking (see Chapters 26 and 27 of this volume by Weiner and Harris and Jankowski and Nyerges for additional information about participatory GIS and GIS and participatory decision making, respectively).

Increasingly, geographers have shown an interest in "mapping the landscape of identity" (Knapp and Herlihy 2002). Ethnicity and landscape are tightly coupled and in some ways exhibit similar characteristics. Just as ethnicity is a concept that shifts with time, space, and point of view, so too landscape is a complex and fluid notion. It is not surprising that ethnicity and identity often reflect context and circumstance. It is no less common for ideas about the use, value, ownership, and possession of land to be unstable, especially when people and places are threatened. The problem, then, for geographers and other social scientists, is how to survey the landscapes of people and place in an appropriate manner when the very subjects of study are so difficult to characterize.

The premise of this chapter is that surveys of people and place are not simply the end result of GIS projects; they are a part of a process through which ideas of ethnicity and landscape are formulated, explored, altered, and articulated. Mapping people and place is a complex process involving choices in methods and techniques that can impact the ways in which territory is perceived as well as the ways in which territory is eventually portrayed or used as the basis for spatial analysis.

Central American Case Studies

To illustrate the interactive relationship between methods and ideas of territory, examples are used from two participatory mapping projects in Nicaragua and Honduras completed over a period of years in the early 2000s (Figure 28.1).

From the spring of 1997 to the fall of 1998, a World Bank funded project to research and analyze the land claims of indigenous communities on the Caribbean coast of Nicaragua was carried out under the direction of the Caribbean Central American Research Council (CCARC – known prior to 2004 as CACRC). This project resulted in the mapping of the claims of 127 indigenous, Garifuna, and Creole communities, many of which had not been depicted on maps before (Dana 1998, Gordon, Gurdián, and Hale 2003). CCARC directed another study in 2002, along the northern Caribbean coast and Mosquitia of Honduras, mapping the claims of the Garifuna and Miskitu communities. Both projects were participatory in nature, linked to land rights and indigenous groups, and were accomplished with the help of GIS and Global Positioning System (GPS) technologies.

Representations of Territory in the GIS Process

The idea of defining territories with specified boundaries is not a modern concept. Clay maps and petroglyphs from as long ago as 2,500 BC appear to show property lines and field boundaries (Harvey 1980). Cadastral maps may have been among the first preserved maps and their history suggests that control of bounded space is a very old notion. Modern notions of national, provincial and other administrative boundaries, and the private and communal property defined within them come out of a long tradition of bounding space. Rivers, coastlines, and mountain ridges have often provided natural linear features with which to bound territory. The less well-defined midpoints of impenetrable regions of wetlands, deserts, or jungles have been used as convenient divisions between adjacent groups. Where territory is not well

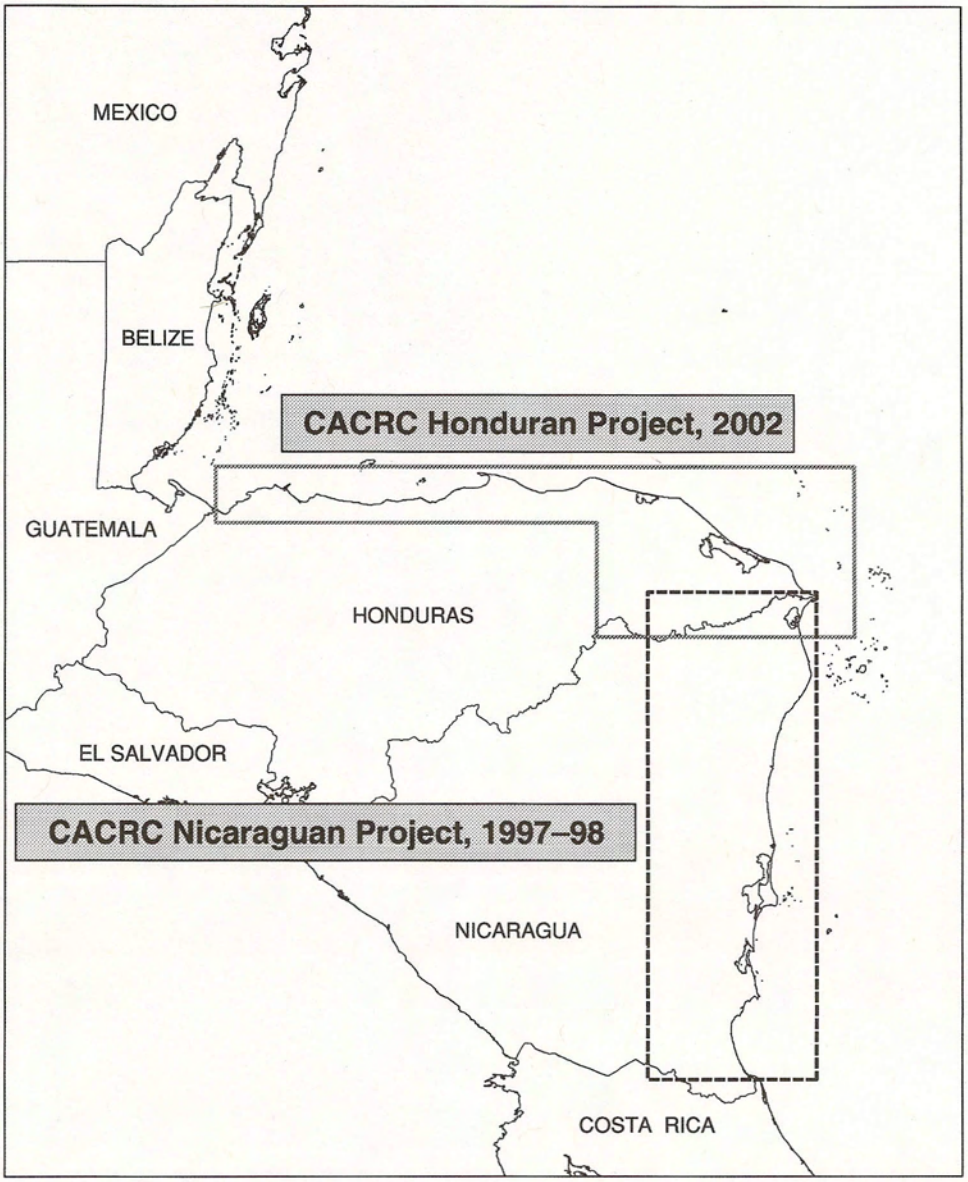

Fig. 28.1 CCARC Central American mapping projects

defined by natural or artificial linear boundaries, divisions between places reflect the patterns on the land made by settlements and land use practices.

When maps became tools of empire, natural features, populated places, and locations in empty spaces on maps were connected with intangible lines that eventually became realized boundaries. In the last few centuries, with the advent of celestial positioning technologies, boundary lines have been constructed with meridians, parallels, or paths between points defined by longitudes and latitudes. Then and now, these conceptual boundaries very often have no relationship to people and places on the ground. In some cases people living on or near national borders, park boundaries, or concession limits may have little or no knowledge of the existence of these lines. More often they have little control over the forces that put these lines on the map and that control events from afar.

Territory is sometimes defined or claimed within an indeterminate spatial extent. Land use patterns, historical claims, built environments, and the significance of certain locations can implicitly define space without requiring boundary lines, either natural or artificial. For communities, ethnic groups, indigenous organizations, or settlers in regions where neither private property nor administrative district boundaries have significant impact, territorial claims may be based on land use within only vaguely agreed-upon limits.

GIS practitioners are familiar with the field and object views of space. Points, lines, areas, and volumes defined by points and directions are the fundamental objects of vector-based GIS. Spaces partitioned into two- or three-dimensional compartments filled with attribute values are the fields of raster-based representations of geographic entities. While modern GIS platforms can handle both approaches, the raster and vector views of the world still impact the way we view territory.

Territory without specified boundaries or limits is not easily defined within a GIS platform. While we are used to grouped and nested polygons, with enclave and exclave features sometimes conceptualized as *islands* or *lakes*, space is usually mapped in vector-based GIS with defined polygons. In raster-based GIS, fields are explicitly filled with contiguous cells that represent unique identifiers signifying connection with a particular territory.

The fluid and seasonally-dependent territories of nomadic groups are also difficult to represent in GIS platforms, whether raster- or vector-based. While both methods can easily handle multiple layers of territorial identification, neither lends itself to views of territory that are not based in concepts of defined, delimited, and demarcated extent. People living within territories neither encompassed by natural boundaries nor constrained by neighboring community extents may not be able to fit their ideas of the land into the bounded spaces of GIS polygons or defined grid cell contents.

We only have to look at the complicated multiple polygons of hunting regions in British Colombia in the "Maps and Dreams" of Hugh Brody (1982) or the "Fifty versions of the Great Plains boundary " in Rossum and Lavin (2000, p. 546) to see the difficulties in trying to represent convoluted space, real or imagined, in GIS. When surveying more complex environments with multiple ethnicities and contested landscapes the difficulty of representing a multiplicity of ideas of territory within the same space can become almost unmanageable.

The Interaction between Method and Result

When territory is not well defined or when its definition is contested, the measurement techniques selected for the survey and the representational models chosen for analysis may influence the ways in which territory is ultimately perceived and defined. In some cases the effects of mapping and conceptions of territory may be beneficial to all concerned. In other situations there may be unintended and unforeseen consequences that can result in an increase in the level of contestation. The hope is that with attention to appropriate measurement and analysis methods and their effect on notions of territory we might be able to do a better job than with methods less in touch with the territories under study.

The vector view of territory is of space bounded by lines and populated by objects at locations of interest. This point, line, and area view of the world gives special significance to coordinates, points in Cartesian space, and to linear boundaries even where none may exist on the ground being mapped. Populated places with considerable spatial extent and complex shapes are often represented on maps by single points. Wetlands, streams, and river networks are sometimes signified by a single line. Intricate distributions of variously defined ethnic groups are located within databases and on maps with discrete linear boundaries. The vector approach often ignores those elements of the territory that do not easily lend themselves to vector descriptions.

Raster-based approaches to mapping usually classify space through rectangular grids of regularly spaced cells, each of which has an attribute described with thematic or numeric attributes. Raster views of territory, especially those that model with multiple layers of grids, allow a conception of territory that is content or use-based rather than one defined by spatial limits. Land use, land cover, ethnicity, elevations, rainfall amounts, and other complex continuous or semi-continuous spatial distributions lend themselves to raster display and analysis. The raster view does not easily handle those cases where territory is defined by the points and lines of political boundaries or where rivers and coastlines form natural linear boundaries. Since each cell in a conventional raster layer can only signify a single attribute value, the raster approach often results in the implication that in a single thematic layer, each point on the ground can only be classified in a single, discrete way.

In most mapping projects, some combination of these vector and raster views is helpful. Conventional land surveying techniques have long been based on the measurement of distances and angles. These are points defined by angles and radii in a local polar coordinate system, resolved using simple planar geometry into points, lines, and areas. GPS receivers measure points in space defined within some local rectangular coordinate system or by latitude and longitude. The result of these measurements made with varying degrees of precision and accuracy should more reasonably be thought of as centers of probability clusters, rather than the dimensionless mathematical point they emulate. Lines are constructed on the map as connections between points. Areas are formed from boundaries made from lines. The noise, biases, and blunders found in surveying and mapping technologies propagate from their original measurement into the line and area features found on final maps. Lines on maps should be considered as having some fixed or variable width rather than as infinitely thin mathematical constructions. Areas defined as mapped regions also share the uncertainty of the points and lines that define them.

When mapping contested lands, approximations may be appropriate even if higher levels of accuracy are possible and affordable. During the 1997–98 mapping period in Nicaragua the US Government was still applying the intentional degradation of the civil service called Selective Availability (SA) to GPS signals. SA added biases of many tens of meters to each satellite signal in a pseudo-random manner that

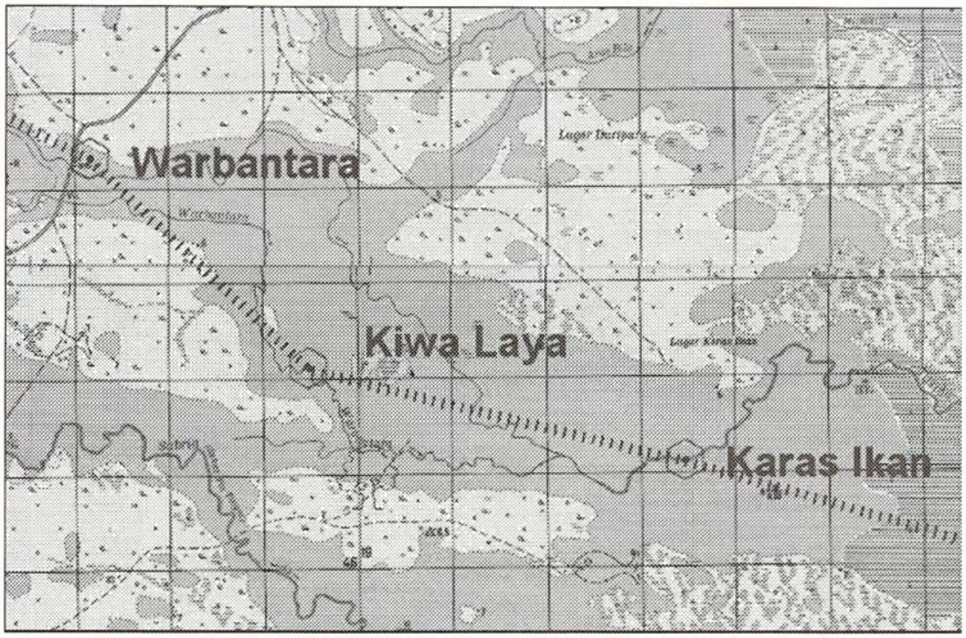

Fig. 28.2 CCARC Nicaraguan map detail with large point symbols and line hatching indicating survey imprecision

caused time-varying biases resulting in horizontal position errors of about 100 m. For this project, mapping using 100 m precision was a desirable feature. Rather than working with a precision that implied some finality and legal weight we preferred a precision that implied approximation. To display this appropriate and useful imprecision, we used large point symbols and hatched boundary lines on the final maps (for example, Figure 28.2).

In a place where territory is not well-defined, methods used in mapping can change views of territory. Local conceptions of territory can be unconstrained by conventional ideas about extents and boundaries. When territory is unmarked and unbounded, a mapping project may result in the territorializing of people and place, changing, for good or bad, the perception of landscape in fundamental ways (Sack 1986). During the Nicaraguan project mapping process many of the 127 communities selected for inclusion in the study chose not to make claims or be mapped as individual communities. Communities, faced with fractures and contested individual boundaries, formed regional groupings that melded into *bloques*, larger regions within which internal boundaries were not measured or mapped. Figure 28.3 illustrates the complex tiling and overlaps in the final maps.

The result of this mapping project was a tiling of territory within the study area that left few of the un-mapped regions sometimes considered "empty" and designated as "state land." Since the purpose for the study was to set out initial claims, not to produce land titles or final demarcation we expected overlaps between claims. Overlaps were common, and are now the subject of considerable negotiation between communities.

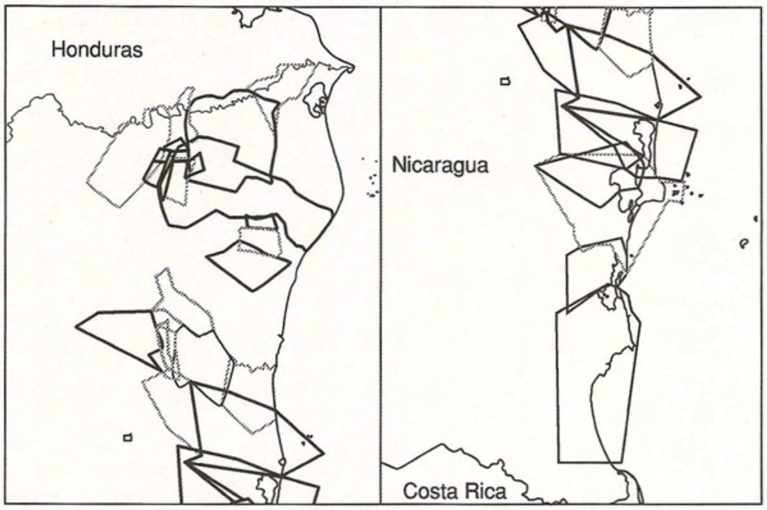

Fig. 28.3 Tiling and overlaps in CCARC Nicaraguan *Bloques*

Point markers signify extents of territories. This does not imply that these monuments are necessarily points along a polygonal boundary. In early Asian empires these point features were often regarded as the end points of conceptual lines emanating from a power center (Anderson 1991, p. 172). In Miskitu settlements along the Caribbean coast of Nicaragua monuments sometimes mark community extent without implying any fixed line between them. If a mapping project is designed to delimit territory with regional boundaries, points previously conceptualized as isolated markers may become the vertices of polygons. Neighboring communities may end up with boundary lines between them that they neither needed nor wanted.

This happened at the beginning of the CCARC Nicaraguan study. We conducted a pilot project with the permission and assistance of the community of Krukira. After community meetings in which ideas of territory and community boundaries were discussed, we set off to find and measure important boundary turning points with GPS. Included were a coco palm at Barra Sahnawala on the coast and the remains of a concrete/rebar monument at Yulu Tingni. That night on a small notebook computer, I prepared the first project draft map (Figure 28.4). The next day community members agreed on the placement of all the monuments but were surprised by my choice of boundary line placement. They all agreed that the straight line I had placed between Barra Sanawala and Yulu Tingni was quite wrong. There was no agreement on how the line might be better placed and no suggestion on the placement of other turning points. In short, the assumption that the boundary should follow a vector between two points was inappropriate for the local conceptions of territory.

Where communities do want boundary lines, the methods used to mark them can change their placement. If paper maps are used, the features selected for inclusion on those maps by the agency that produced them can influence the placement of boundary turning points and connecting lines. If remote sensing is used, features

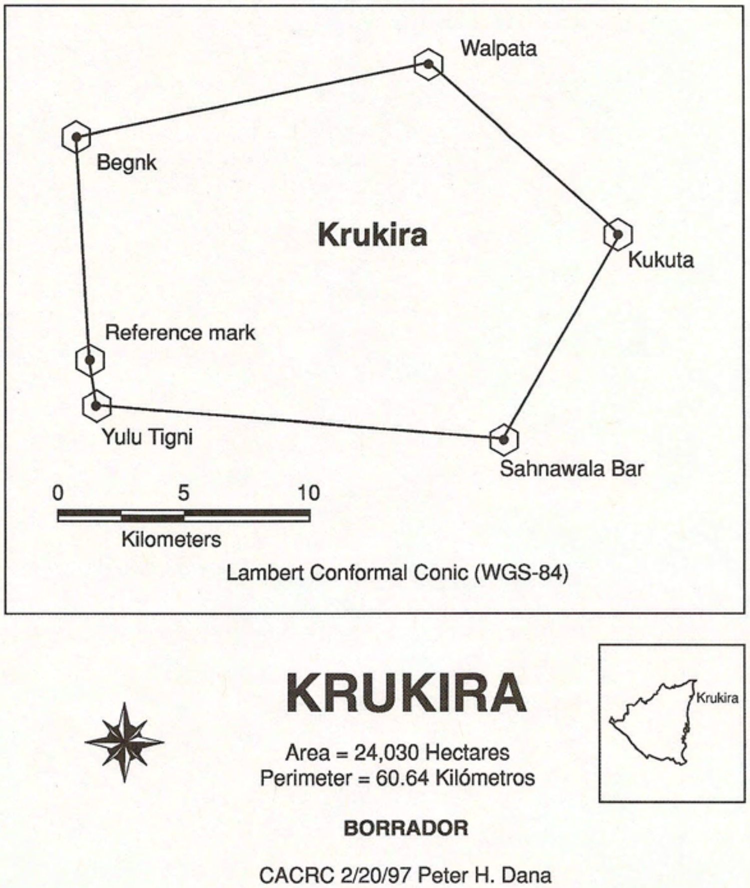

Fig. 28.4 Draft map of Krukira with straight lines between points

with recognizable visual patterns on aerial photographs or particular electromagnetic signatures in satellite imagery may take precedence over sacred sites, traditional hunting regions, or the sources for medicinal plants, that are important to communities but utterly lost to those technologies.

If a project selects traditional surveying equipment to help define boundaries, the resulting boundary lines may well reflect the line-of-sight path that the demarcation team follows as they proceed, often an easier and simpler path than the more difficult transect through swamps, jungles, and difficult terrain that might have formed the boundary of the community were a less arduous method chosen.

Appropriate Technologies

Measurement technologies should be selected that respect and faithfully reflect local perspectives on territory. Approaches to mapping people and place range from informal interviews and sketch maps to remote sensing and GIS displays. In between these is a broad range of measurement tools and information gathering techniques (Poole 1998).

Mapping from interviews, narratives, or discussions can be useful as part of a mapping project or as the fundamental mapping methodology. Historical and current land use, from specific agricultural zones to more vaguely defined regions of ceremonial importance, may be more easily determined through interviews than from any analysis of imagery or ground survey. Both of the CCARC projects were based on ethnographies gathered by trained investigators. These detailed histories of occupation and descriptions of past and present land use were important for establishing the validity of land claims.

Sketch maps, from those drawn in the earth during an informal discussion to those carefully drafted on waterproof paper during a visit to a new area, can be useful at every stage of a mapping process. Often suggested as a tool in the map design process, informal sketching has been called "graphic ideation" (Dent 1999, p. 239). "Compilation worksheet" is the more formal term for the draft map produced during the map design process (Robinson, Morreson, Muehrcke, Kimerling, and Guptill 1995, p. 426). We often used sketch maps to work out conceptions of territorial boundaries and land use such as the sketch map made during a community visit to Auka, Honduras shown in Figure 28.5.

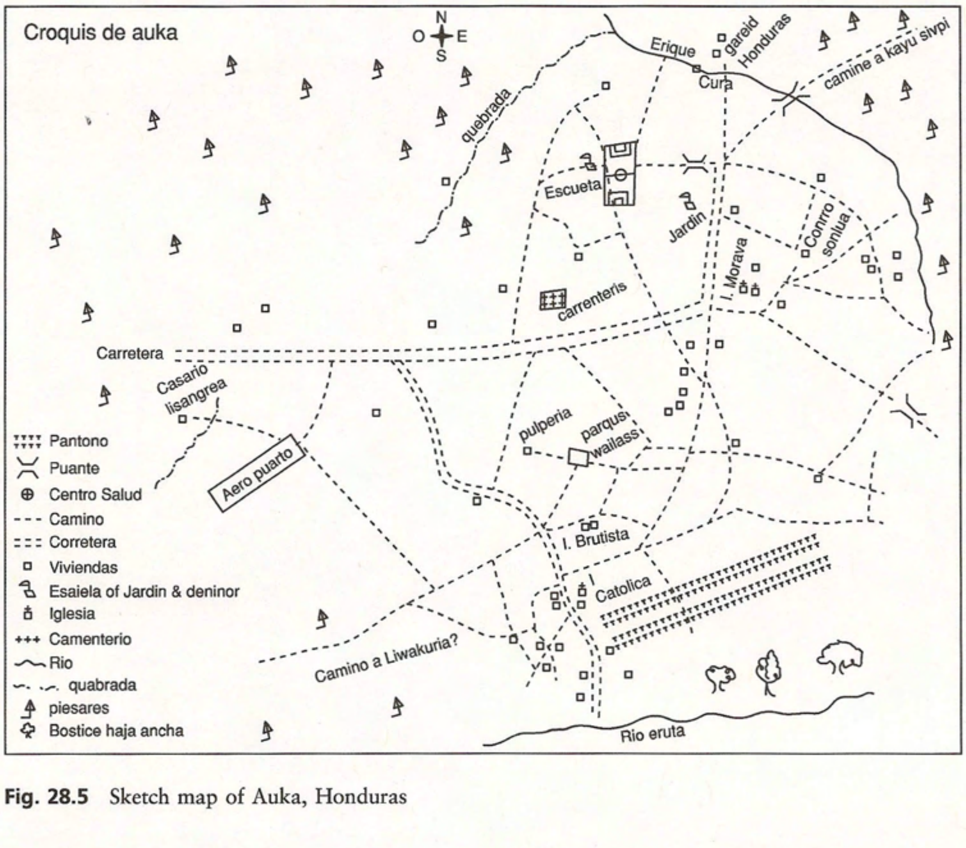

Fig. 28.5 Sketch map of Auka, Honduras

Base maps are general-purpose reference maps that define the basic geographic features of a region (Muehrcke, Muehrcke, and Kimerling 2001, p. 188). Thematic maps produced in a participatory mapping project can be made by overlaying new information on a base map. Base maps can be produced especially for a mapping project, but in most places some form of base map already exists. Existing base maps need to be used with care. They have often been produced by agencies with military or commercial agendas. The places and the place names on maps may reflect these agendas more than they do the ground truth. Roads connecting mines and ports may be present while paths more important to community members may not be shown at all.

Base maps that exist in digital form may be expensive or tightly controlled by mapping agencies. Scanning paper maps (especially in color and in detail) is expensive and sometimes difficult without special equipment. All maps contain omissions, generalizations, and exaggerations. Base maps produced by and for groups not concerned with community conceptions of territory may not contain any useful features to aid in community mapping. Unfamiliar grids and coordinate systems, combined with toponyms in the language of the mapping agency may have little meaning to community members and may make mapping more difficult rather than aid in participatory mapping. Appropriate base maps that reflect the conceptions of territory held by participants may be difficult or impossible to find.

The base maps we used in the CCARC projects suffered from some of these limitations. Maps of both Nicaragua and Honduras are available as 1:50,000-scale topographic sheets. In general they use Spanish names and often do not contain information important to indigenous communities. They almost never contain monument symbols or boundaries that represent communities. Produced usually by military or resource management agencies, existing maps sometimes reduce communities to just a few symbols on a map. Paths, health centers, churches, and other features are often not portrayed on these reference maps. Compare the sketch map of Auka in Figure 28.5 to the Honduran government topographic map of the same region in Figure 28.6. With the contour lines removed, the latter would be a very empty map.

In the CCARC projects, we tried to keep pre-existing maps out of the process of community discussions of land tenure. Maps sometimes influence decisions by deflecting interest from actual territory in favor of the simplified versions they depict. Administrative boundaries, particular roads and streams selected for mapping, settlement patterns that may no longer reflect the status of neighboring communities, and even the grid pattern superimposed on the mapped ground can shape views of the land. Once conceptions of territory had been established there were many times when maps were useful in the field particularly in navigating from place to place once sketch maps and discussions had determined community extents. Scanned maps became the base maps on which community boundaries were placed for final display. CCARC had to scan, crop, and georegister 103 Nicaraguan map sheets. In Honduras we had access to a complete set of 1:50,000-scale maps already scanned and stored in MrSID format.

There are many time-honored methods that are sometimes overlooked when a GIS-based project is planned. There are still plenty of places where 120–240 volt AC power for recharging a battery is not available. Solar-based recharging systems

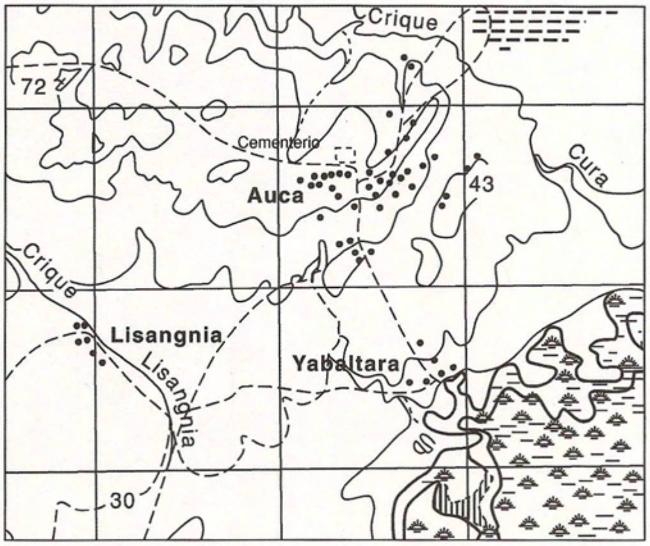

Fig. 28.6 Topographic map of Auka, Honduras

are heavy, fragile, and may not be able to handle the power requirements of multiple devices. There are places where even finding a few "AA" batteries is a challenge. The Caribbean coast of Nicaragua and the Mosquitia of Honduras are challenging environments. Outside of the towns of Bilwi, Bluefields and Puerto Lempira, electrical power is intermittent or unavailable. Finding a set of "AA" batteries is difficult or impossible in many places. These Caribbean coastal regions experience some of the highest annual rainfalls in the tropics. This is not a place for keyboards, electrical cables, rechargeable batteries, or dependence on computers. For both projects we designed very "low-tech" measurement approaches. Participants carried waterproof boxes into the field containing low-cost water-resistant GPS receivers, extra batteries, waterproof notebooks, pencils, and inexpensive magnetic compasses (Figure 28.7).

The magnetic compass is a valuable tool in mapping projects. At the least it can keep investigators oriented in the field. Relative angular measurements can be made to a few degrees of arc irrespective of magnetic variation, allowing the compass to act as an alidade. When combined with the practiced pacing of distances, the compass can be an effective tool for a reconnaissance survey. Magnetic variation, the difference between true north and the direction of the magnetic poles is marked on most topographic map sheets. Variation changes over time and so absolute direction requires up-to-date variation information. Local anomalies can cause significant local changes in variation so projects should be wary of absolute measurements made with magnetic compasses. Use of a magnetic compass within a range of 1,000 km of the magnetic pole is not advised. An important consideration for participatory mapping projects is the problem of magnetic dip. The north pole of a magnet points toward the magnetic north pole which is not in a direction horizontal to the local level surface, but rather down, in a direct line to the pole through the Earth. The

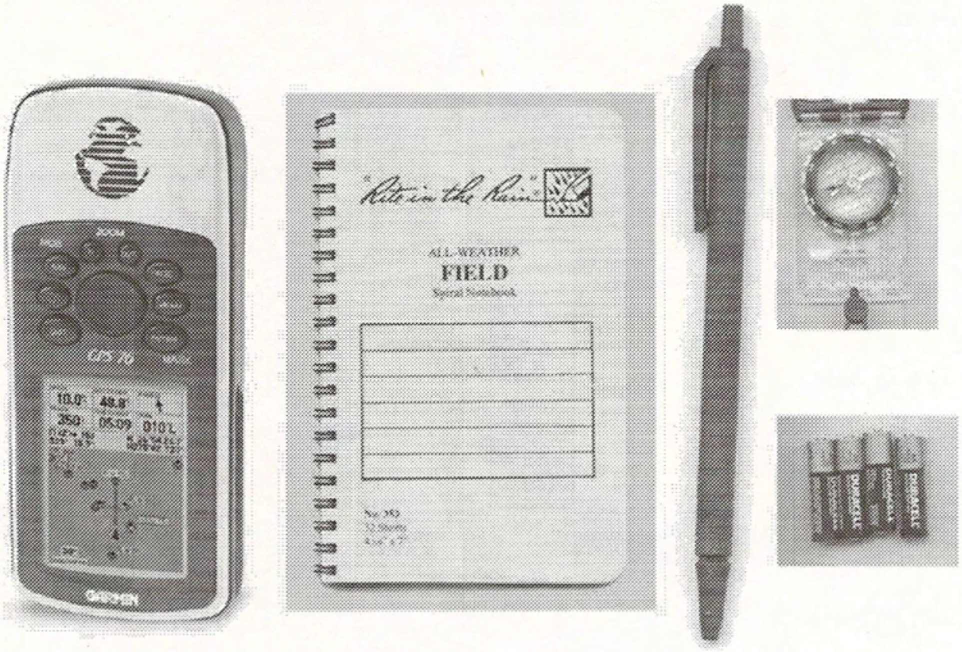

Fig. 28.7 Waterproof kit contents: GPS receiver, field notebook, pencils, compass, and extra batteries

needle of a compass must be adjusted for this "dip" to keep it from scraping the base of the compass as it turns. Magnetic compasses are adjusted by the manufacturer to work within specific latitude ranges (five degree latitude ranges are common). There are newer "international" or "global" compasses with a separate needle and magnet that work at all latitudes. During both the Nicaraguan and Honduran projects where obstructions made GPS measurements at boundary points, or, as in the case of small islands that had to be measured offshore from small boats where it was impossible to reach the boundary point, participants included compass bearings and estimated distance from the GPS receiver to the point. Final point positions were computed in the GIS from the measured point and the distance and magnetic bearing corrected for local variation.

The alidade and plane table can still be effective mapping tools, especially for mapping in the field under conditions that might make one-time mapping the only practical method. Based on the intersections of lines of sight from two or more points, the alidade is simply a ruler with a sight on it, usually an optical telescope attached to a metal rule. The alidade is placed on top of a piece of paper attached to a "plane table," a drafting table on a tripod. Leveled and aligned along a baseline, the plane table supports the alidade which is pointed at objects to be mapped. Moved from place to place, the intersection of lines to common points marks their position on the paper map as the process continues. By combining intersecting lines for more than three points the process allows the mapper to estimate error and correct for mistakes while still in the field. Without batteries, computers, or communication systems, these are still viable tools for participatory mapping projects. As a point-demarcation process, the technique lends itself to conceptions of territory that are based on discrete point features.

Positioning with sextant and celestial almanacs is a means of finding latitude and longitude at sea. On land, with the stable platform of a leveled tripod, latitude and longitude can be determined to within a few meters. Requiring precision optical vertical angle measurements, access to precise time, and accurate almanacs describing positions of objects in the sky, these methods are still used by surveyors to establish points of beginning and base lines. They are perhaps best used to establish a few geodetic points where GPS or other more accurate and more easily used methods are not available.

The surveyor's theodolite is an optical and mechanical angle measuring device that allows horizontal and vertical angle measurements with respect to a baseline and a local level plane defined by gravity. Combined with a tape (or chain) for measuring distance, the theodolite can measure the metes and bounds of a survey traverse. Theodolites are expensive, require calibration, and take considerable training and practice to use effectively. Damage that occurs in the field will not likely be repaired without expert help. The traverse approach to area boundaries with such instrumentation requires a clear and level line of sight from one traverse point to another. The tape must be physically connected from point to point, making boundary surveys across swamps, through jungles, and along rivers difficult.

Where electrical power can be used and where access to the supporting supplies of batteries, cables, computers and disks can be found, one can manage projects with all of the tools available to the modern mapper or surveyor. Where temperature, humidity, and security allow their continued use, they can be effective tools. One sharp jolt from a fall or a bump in the road can ruin or damage an expensive device required for project completion. Perhaps worse, difficult conditions can cause an instrument to become inaccurate, often without any indication of a problem until after the survey. The digital theodolite can measure angles and automatically record them on a small handheld calculator or data collector. They require battery recharging and considerable care. They come with or without laser pointers to facilitate alignment with targets. Visible laser alignment aids can only be used within 50 m of so of the instrument. Infrared laser measurements of distance can be made with Electronic Distance Measurement (EDM) devices. Prism reflectors placed at a target return a coded laser signal to the EDM device, and range is calculated from travel time. These devices can measure ranges as long as 4 km under good atmospheric conditions. Normal operating range limits are in the 2 km range. Range accuracies are typically 2 mm plus two parts per million (4 mm total over a 2 km distance). Newer reflectorless devices can measure the return signal from a target without a prism, but are only useful for distances of less than 100 m. Use of non-prism EDMs can introduce blunder errors when the reflected signal is not from the intended target. In the field, small EDM devices can replace or augment the tape or chain to provide distances without the requirement for a physical path between one point and another. Measuring across rivers or gorges can be simplified through the use of EDM.

The Total Station, an electronic theodolite with digitally encoded angle measurements combined in a single instrument with EDM, can measure and record both angles and distances. Usually coupled with handheld data collectors these instruments, which can measure angles to between 2 and 5 arc-seconds, have largely replaced the conventional theodolite and chain. The Total Station is expensive (in the range of US$10,000), heavy (10 kg), and requires regular recharging of batteries.

Binoculars with built-in magnetic compasses can provide relative angle measurements over long distances. Costing in the range of US$500 these devices are sold to mariners and so can often be found in waterproof configurations requiring no batteries (some require battery power to illuminate the compass); they can be valuable aids to mapping projects. Incorporating EDM laser techniques within handheld binocular packages, rangefinding binoculars can be used as lightweight total stations. They can be used to measure distances over ranges as long as 2 km to accuracies of 2–3 m. These do require batteries, but for field work and preliminary surveys they can be effective tools in mapping projects. Laser rangefinders with approximate angle measuring capabilities (about a half a degree of arc) cost about US$3,000 and can be used as handheld replacements for the Total Station when high accuracy is not required. They make useful accessories for GPS projects that require offset range and bearing measurements.

GPS Approaches

The fundamental concept of GPS is the estimation of three-dimensional point position in a geodetic reference system from measurements of the relative arrival times of satellite signals. As a point positioning system, GPS lends itself to projects in which territory is conceived of as discrete points which form either turning points in polygonal boundaries or represent the centers of places. GPS can be used to measure points, paths between points, and the spatial extent of areas. There are three major categories of GPS methods. Unaided code-phase GPS is the use of the civil GPS service with a single receiver that tracks the GPS codes, resulting in horizontal accuracies of between 2–20 m. Differentially corrected code-phase GPS can provide horizontal accuracies of between 1–2 m within 300 km of a suitable reference station supplying corrections to the GPS signals. Carrier-phase GPS is always differential in nature and can provide position accuracies of a few centimeters within 10–30 km of a suitable reference station. These three techniques differ significantly in their accuracy, cost, and complexity.

Unaided code-phase GPS

The US Department of Defense maintains GPS. A civil service is provided that allows unrestricted access to part of the GPS signal structure. The C/A code (coarse acquisition code) contains timing edges that are used within a GPS receiver to measure relative arrival times from each tracked satellite. The timing edges are coded with a repeating sequence of bits such that each millisecond can be resolved into 1,023 distinct intervals. Fractions of an interval can be measured with precisions of a few nanoseconds (three nanoseconds is about one meter of range). System information, satellite clock corrections, and satellite orbital data are contained within the Navigation Message broadcast by each satellite. The GPS receiver uses the C/A code arrival times and the Navigation Message from at least four satellites to resolve the common clock offset from the relative arrival times in order to compute the three-dimensional position of the receiver. GPS receivers typically track all the satellites their antennas can acquire and produce position reports in latitude, longitude, and height for display or recording.

Ionospheric and tropospheric signal delays, clock and orbital data errors, and local reflections result in position accuracies of between 2–20 m depending on the number of satellites tracked and the geometry of the receiver-antenna with respect to the satellite positions in space. Because the satellites are always moving, this geometric relationship and the combination of satellites in view are always changing. All GPS receivers must have a clear and unobstructed view of the sky in order to acquire and track the necessary GPS satellite signals.

Differential code-phase GPS

A special purpose GPS receiver at a precisely known location can compute the differences between the relative ranges it measures and those predicted for that location. These differences are the basis for Differential GPS (DGPS) corrections that can mitigate the bias errors from atmospheric delays and system errors that are common to a reference receiver and a remote receiver up to a few hundred kilometers away. The DGPS corrections are computed for each satellite and are range-domain corrections. They are not position-domain corrections. One cannot simply shift the position of a remote receiver based on the position error measured at the reference receiver unless both receivers are tracking the same set of satellites at the same time, have the same geometric relationship to the satellites, and are using identical clock and orbital data sets. This commonality in the position domain is almost impossible to achieve. DGPS works by providing the remote receiver with range and rate of range change corrections for each satellite. These are then used to correct the measured ranges used in the position solution in the remote receiver. When the reference receiver is close to the remote receiver much of the bias error is common and can be differentially removed. Local reflections (multipath) and receiver-induced errors cannot be removed by DGPS. In situations where the remote receiver geometry or signal strength is insufficient DGPS cannot help.

DGPS corrections can be applied in real-time if a radio link is available to send reference station corrections to the remote receiver. This requires licensing and maintaining a radio link that can reach the remote receiver. There are an increasing number of public and private sources for real-time DGPS corrections. The US government operates the Wide Area Augmentation System (WAAS). This system is based on a network of reference stations that are used to produce correction signals that are transmitted to receivers over communications satellite links in a format that is relatively simple for GPS designers to incorporate into GPS receivers. Where a WAAS-enabled GPS receiver can track either of the two WAAS satellite signals, it can usually estimate position to within 2–3 m. Care must be taken not to use WAAS corrections outside of the regions for which corrections have been calculated. In parts of Central America, WAAS signals can be received but their use can actually degrade rather than enhance position accuracy. Low frequency beacons are used by many nations to provide coastal coverage for maritime use and can be used inland as well where signal strengths allow. Most of the US coast and the east and west coasts of Canada are covered by transmitters operated by the US and Canadian Coast Guard. Several commercial communications-satellite based DGPS services offer coverage over much of the world.

For post-processed DGPS, a receiver capable of saving DGPS data files is needed along with a local DGPS reference station equipped to provide files for post-processing. Dedicated DGPS reference receivers can be established at a cost of about US$20,000 including the computer required to log data for post-processing. While there are hundreds of Community Base Stations (CBS) located throughout the world, locating one and obtaining permission to access to the data files can be difficult. Recent versions of Trimble's Pathfinder Office software include Internet addresses for hundreds of cooperating CBSs, but there are hundreds more that are not part of this list.

Carrier-phase surveying

Special purpose GPS receivers can track both the code edges of the civil GPS signals and the microwave signals that carry them. Tracking the "carrier" signal makes it possible to measure relative arrival times to accuracies of about a centimeter. The technique is limited because these carrier-phase measurements are difficult to resolve into relative ranges. Unlike the C/A code edges there is no marking that differentiates one carrier wavelength cycle from another. In addition, the signal-to-noise ratios for carrier-phase measurements are lower than for C/A code-phase measurements. Special hardware is required to track these low level signals and complex software methods are required to resolve wavelength ambiguities.

Static techniques have been developed that can provide centimeter relative ranges with respect to the position of a reference receiver within 30 km of the remote receiver. Software must have access to the continuous measurement of carrier phase at both receivers. These systems cost from US$10,000 to US$25,000 and require considerable training to operate. Real-time-kinematic (RTK) techniques make it possible to move the remote receiver while making relative position measurement with respect to a reference receiver. RTK techniques require a special RTK reference receiver within 10 km of the remote, a continuous radio link between reference and remote, and the simultaneous tracking of five or more satellites at both receivers. These restrictions, the additional need for training, and the expense (these RTK systems cost more than US$50,000), make RTK difficult to use in many projects.

Data attribute collection

Whatever GPS technique is used, data attribute collection must be considered before, during, and after a mapping project. Names, distinguishing features, topological connections, entity attributes, times, dates, and quality control information are all required in the data collection phase of a project. While inexpensive (some around US$100), recreational GPS receivers have very limited capabilities for recording more than a time, date, position, and a name. Complex mapping projects will require some form of data collection method, devices, and procedures. Professional GPS equipment suites usually include some form of data attribute collection software and hardware.

These systems consist of a dedicated computer or a program resident in a notebook or handheld computer. Attribute collection software platforms have functions for defining data dictionaries or forms for entering attributes. A data dictionary predefines fields and menus that enable the operator to quickly and efficiently select from attribute choices or fill in alpha-numeric records. Data collection software will usually attach time, date, geometry, and tracked satellite lists to each record. Newer palm-sized devices that attach to GPS receivers can be programmed to accept data attributes in both text and graphic format. Figure 28.8 shows a "Pocket PC" running ESRI's ArcPad software connected to an inexpensive WAAS enabled DGPS receiver with external antenna.

For both CCARC projects, where power and maintenance of electronic equipment posed a serious problem, we developed a "low-tech" data collection approach. We held workshops in Nicaragua and Honduras teaching the fundamentals of geodesy, GPS, and GIS. Investigators and community participants then went into the field to existing or new boundary turning points and recorded position information and

Fig. 28.8 DGPS receiver and pocket PC with ArcPad data collection software

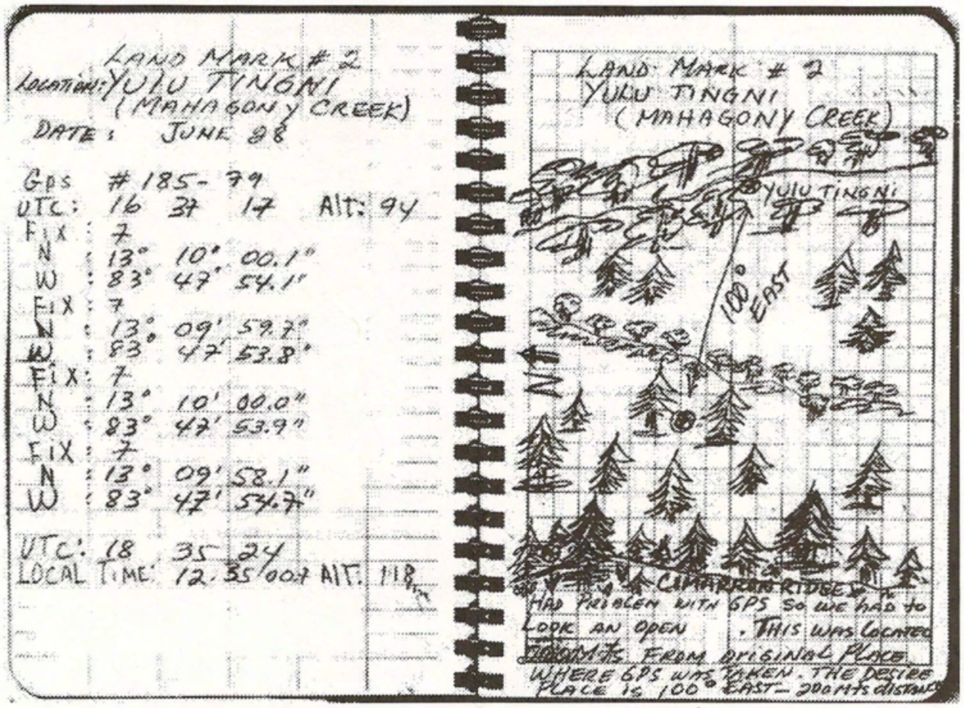

Fig. 28.9 GPS waterproof notebook pages

sketches of locations in waterproof notebooks (Figure 28.9). Crucial in this process was the construction of preliminary community maps with the order of points carefully marked. To define a specific polygon the order of the points is required. In both projects we experienced difficulties when investigators and participants had trouble defining point order unambiguously.

Because most of the communities we helped map seemed to perceive boundary turning points as an appropriate way to define territory, determining the locations of these points was central to the projects. Because the land claims resulting from these projects were contested between communities and between communities and other agencies it was important that communities should show that they really did occupy and use these territories right up to the boundaries. Participants understood the symbolic importance of occupying and physically measuring turning points. They often made extraordinary efforts to reach and measure points at the extent of their lands. For the most part investigators were able to reach points by boat, vehicle, or on foot. Most of these accessible points could be directly measured while others required GPS measurements from a few hundred meters away. Combined with compass bearings and distance estimates, these indirect GPS readings were converted later in the GIS to boundary point position. In many communities, natural line features such as streams and coastlines formed community limits. In order to incorporate these boundaries into community maps, we had to establish the geodetic

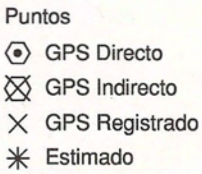

Fig. 28.10 Position types: Direct, indirect, registered, and estimated

position of these features, often misplaced on maps or missing in digital databases. In these cases we asked participants to measure enough points along streams and coastlines to establish their correct position in space. Then we were able to place the natural features on georegistered maps. Where turning points were inaccessible to participants because the terrain was too difficult or because land owners prevented access, we encouraged participants to use maps or other descriptions to "mark" points they could not reach to occupy safely.

With lessons learned in Nicaragua we developed a methodology for point measurement and description in the Honduran project that seemed to handle these different cases quite well. We defined four point types: (1) *Direct GPS* points, where the receiver was co-located with the point; (2) *Indirect GPS* points where GPS was not possible at the point but could be measured at some distance and direction away; (3) *GPS Registered* points that were established from maps and databases after GPS measurements established the position and orientation of natural features; and (4) *Estimated* points, with a geodetic position estimated from maps or imagery. This last set of points provides the least authority in establishing land claims. Figure 28.10 shows each of these point types and their symbolization on final maps.

Point information, including place names, position, and the all-important point order in completed field notebooks was entered into Excel spreadsheets for importation into GIS. Offset range and bearing computations and geodetic datum shifts were all accomplished within the GIS process. In workshops conducted in Nicaragua and Honduras, investigators produced draft maps of community boundaries on 1:250,000-scale scanned base maps.

Draft maps with measured community boundaries were returned to communities for land use annotation. In this validation phase, communities verified or asked for revisions of boundaries or additional turning points. Land use, crucial for the development of land claims, is a difficult concept in regions of multiple and contested uses for territory. Land use is also perhaps the most difficult attribute to collect in the field. There are so many conflicting, overlapping, and contested uses for land that any attempt to map land use is bound to be a compromise. For the CCARC projects, focused on land claims, land use was determined and categorized differently than it often is within the resource-management tradition of land cover/land use schemes. We were as much interested in land significance as in vegetation cover or the planned use of lumber product by forestry agencies, so we developed, with the help of the communities, a set of land use categories that had significance to communities, representing their traditional and customary land uses, irrespective of what remote sensing might decide through the analysis of electromagnetic

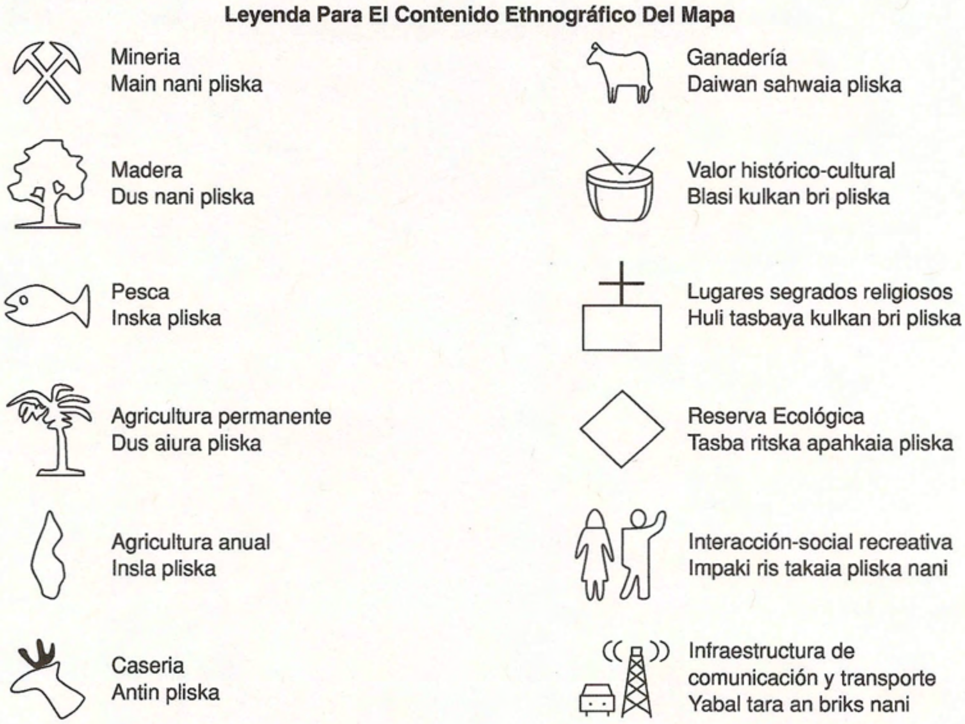

Fig. 28.11 Land use categories and symbols for Nicaragua

signatures. Many so-called *land use* schemes include categories that are more appropriately termed *land cover*. For instance, forested land is a category that does little to suggest the hunting and fishing activities or fallow status that might be the actual land use. To help establish and defend land claims CCARC categories included places of historical significance, social gathering places, and ecological reserves. Figure 28.11 shows the land use categories in Spanish and Miskitu developed by community members for Nicaragua. Figure 28.12 shows the land use categories for Honduras in their Spanish/Garifuna and Spanish/Miskitu versions.

Map Production and GIS Analysis

GIS were used as the basis for map-making in both projects. MapInfo was selected for Nicaragua because at that time it was the only entry-level platform that could handle coordinate system and geodetic datum shifts without special scripting. In Honduras, ESRI's ArcView 3.x was used in many government, resource agency, and non-governmental organization settings. To maintain a compatibility with a variety of organizations and to make distribution of project results easier, we selected ArcView 3.x, which by 2002 had added rudimentary coordinate system and datum conversion capabilities to earlier versions.

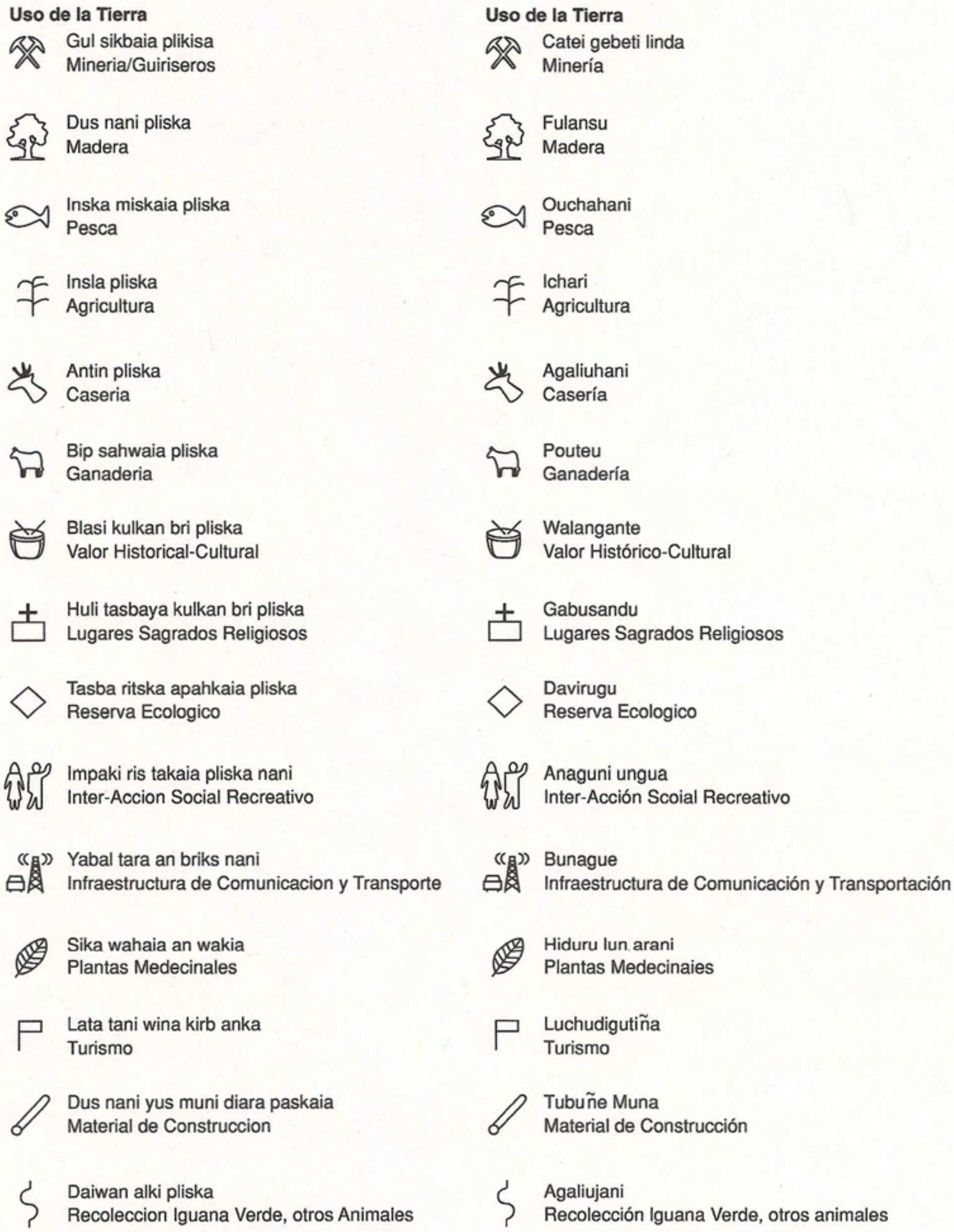

Fig. 28.12 Land use categories and symbols for Honduras

Scanned 1:50,000-scale maps were used as base maps. Geodetic datum and coordinate system conversions were accomplished to keep all layers in a common coordinate system. Community boundary points with name, longitude, latitude, and point order were processed with a MapBasic or Avenue script that resulted in

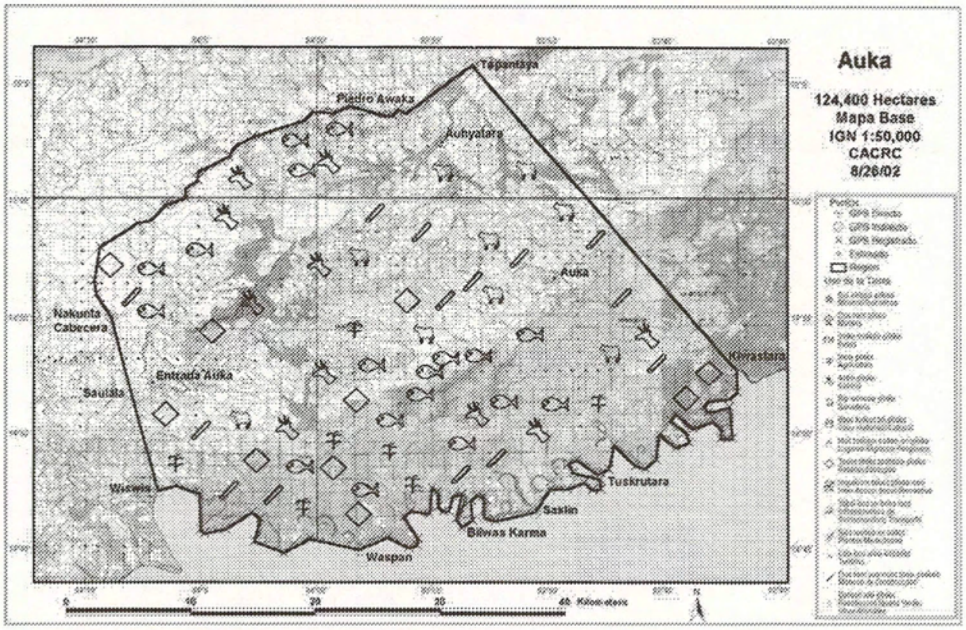

Fig. 28.13 Final map of Auka, Honduras

point and polygon files for use in the GIS process. Land use symbols were then transferred from the draft maps to point databases. Named boundary turning points, community boundary polygons, and land use symbol point files were mapped over the scanned base maps. GIS were used to produce area and perimeter values and to compute the area of overlaps between communities. Figure 28.13 illustrates a completed community map for the Honduran Mosquitia.

GIS were the basis for mapping and were used for measurements of distance and area, but a GIS-based project offers much more. Once information is captured in georeferenced layers, all sorts of analysis become possible. As an example, we found that land use, so critical for land claims, was often very differently designated by adjoining communities along boundaries and within overlaps. Figure 28.14 shows the areas of matching and non-matching land use in the overlap between two Honduran communities.

Because all our project information was in GIS form, we were able to use *allocation* (*proximity*) and cost-weighted allocation analysis to quantify the spatial extent implied by land use point symbols placed on maps. We were able to use spatial statistics such as the kappa coefficient to evaluate percentages of land use correlation in overlaps or along boundaries between communities. Using GIS processes we measured the relationship between regions of matching land use and proximity to streams that forms much of the visual pattern in Figure 28.14. We have since found similar land use differences in Nicaragua and in adjoining communities in Belize as depicted in another participatory mapping project (Toledo Maya Cultural Council and Toledo Alcaldes Association 1997).

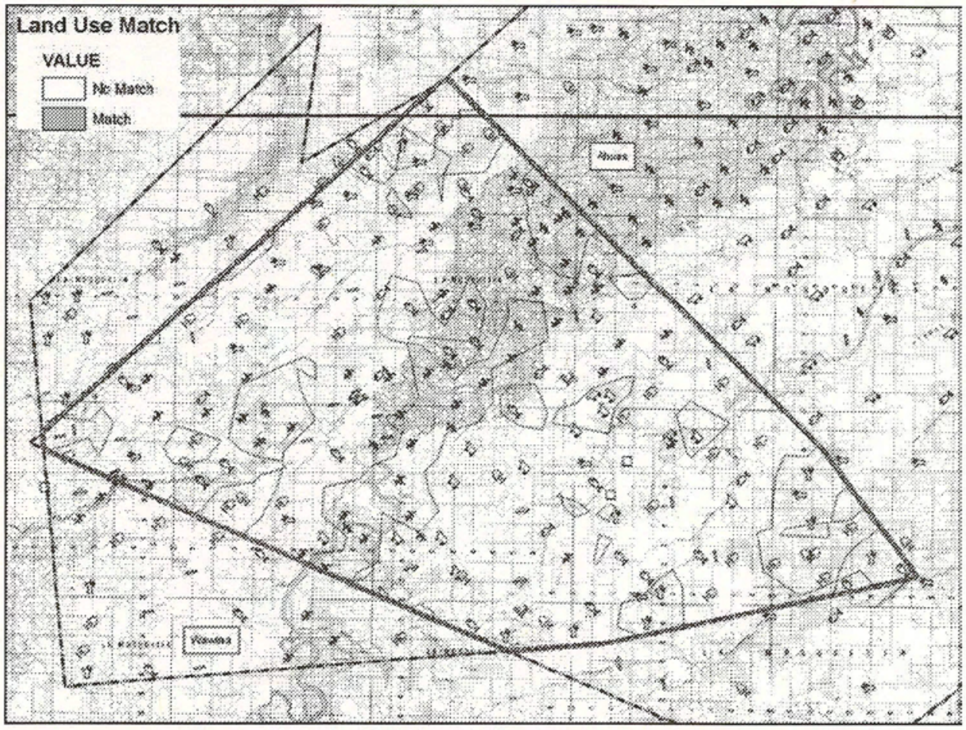

Fig. 28.14 Land use differences in overlap between Ahuas and Wawina, Honduras

CONCLUSIONS

Surveys of people and place should attempt to discover and use methods and technologies that reflect local conceptions of territory. Boundary and point-based conceptions of territory lend themselves to point measurement methods, vector cartographic representations, and vector-based GIS processing. Where land use defines territory, remote sensing, raster-based mapping, and raster-based GIS may be more appropriate. Solid lines defining territory may be inappropriate where territory is contested or poorly defined. In many cases mapping processes and notions of territory will interact with each other.

The selection of mapping technologies such as interviews, sketch maps, and remote sensing that favor land use mapping may be more appropriate for some projects than boundary-based technologies such as conventional traverses or GPS measurements that favor bounded conceptions of territory. Relative position measurements may require complete boundary traverses where such point-to-point access to land is dangerous or costly. Injudicious selection of base maps, such as selecting a base map produced by an agency of an unpopular government, can change a locally controlled participatory mapping project from one with an appearance of self-determination to one that requires that its community boundaries be based on the product(s) of a faction competing for land rights. Selection of high-precision survey techniques may require hundreds of point measurements to accomplish a boundary survey that would more appropriately be accomplished with just a few points in a reconnaissance survey. Contested boundaries might be better measured with approximate methods to avoid confrontations and resistance to modification with respect to the claims of neighboring communities.

Map projections, geodetic datums, and coordinate systems should be selected with respect to scale and accuracy requirements while respecting local independence from the reference systems often imposed by colonial powers or military mapping agencies. Surveying methods that use independent measurements of absolute position may be difficult to repeat or to link to physical features on the ground, making legal land titling impossible in a context in which local laws require reference to physical ground features or existing boundary markers. In the CCARC projects, for example, there is often no direct link between monuments on the ground and the GPS-derived points. This makes legal land tenure claims using the CCARC data sets difficult, lessening the chance that these approximate boundary claims will result in disputes over exact boundary placement.

Problems of supply, maintenance, and replacement of sophisticated electronic equipment, while not unique to mapping in remote areas, are often insurmountable where budgets typical of participatory mapping projects are limited. Climatic conditions, often extreme in tropical or polar environments, can cause failure of instrumentation on the ground. Cloud cover can render some remote sensing methods useless. Language-based processes embedded in modern electronic devices may not be suitable for use in many parts of the world. GIS processes bring to a project assumptions about space embedded in the software. Current GIS are limited in their ability to handle temporal change, uncertain boundaries, and multiple or contested land use. If local notions of territory are fluid and shifting, an entirely new or modified GIS platform might be required to handle complex or different notions of territory.

Ideas of territory and the mapping of territory are intertwined in an inseparable relationship. The ways in which territory is perceived influences its portrayal on maps, and methods used to make maps can change notions of territory. Any GIS-based mapping project is at the juncture of this process. Successful surveys of people and place require a synthesis of appropriate technologies and local participation.

REFERENCES

Anderson, B. 1991. *Imagined Communities.* London: Verso.

Brody, H. 1982. *Maps and Dreams.* New York: Pantheon Books.

Chapin, M., Lamb, Z., and Threlkeld, B. 2005. Mapping Indigenous lands. *Annual Review of Anthropology* 34: 619–38.

Dana, P. H. 1998. Nicaragua's "GPSistas": Mapping their lands on the Caribbean coast. *GPS World* (September): 32–42.

Dent, B. D. 1999. *Cartography: Thematic Map Design.* Boston, MA: McGraw Hill.

Gordon, E. T., Gurdián, G. C., and Hale, C. R. 2003. Rights, Resources, and the Social Memory of Struggle: Reflections on a study of indigenous and black community land rights on Nicaragua's Atlantic coast. *Human Organization* 62: 369–81.

Harley, J. B. 1988. Maps, knowledge and power. In D. Cosgrove and S. Danials (eds) *The Iconography of Landscape: Essays on the Symbolic Representation, Design, and Use of Past Environments*. Cambridge: Cambridge University Press, pp. 277–312.

Harvey, P. D. A. 1980. *The History of Topographical Maps: Symbols, Pictures, and Surveys*. New York: Thames and Hudson.

Knapp, G. and Herlihy, P. 2002. Mapping the Landscape of Identity. In G. Knapp (ed.) *Latin America in the 21st Century: Challenges and Solutions*. Austin, TX: University of Texas Press, pp. 251–68.

Monmonier, M. 1991. *How to Lie with Maps*. Chicago: University of Chicago Press.

Muehrcke, P. C., Muehrcke, J. O., and Kimerling, A. J. 2001. *Map Use: Reading, Analysis, Interpretation* (4th edn). Madison, WI: JP Publications.

Poole, P. 1995. Land Based Communities, Geomatics, and Biodiversity Conservation: A Survey of Current Activities. *Cultural Survival Quarterly* 18(4): 74–6.

Poole, P. 1998. Appropriate geomatic technology for local earth observation. *Yale F & ES Bulletin* 98: 156–66.

Robinson, A. H., Morreson, J. L., Muehrcke, P. C., Kimerling, A. J., and Guptill, S. C. 1995. *Elements of Cartography* (6th edn). New York: John Wiley and Sons.

Rossum, S. and Lavin, S. 2000. Where are the Great Plains? A Cartographic Analysis. *Professional Geographer* 52: 543–52.

Sack, R. D. 1986. *Human Territoriality: Its Theory and History*. Cambridge: Cambridge University Press.

Toledo Maya Cultural Council and Toledo Alcaldes Association. 1997. *Maya Atlas: The Struggle to Preserve Maya Land in Southern Belize*. Berkeley, CA: North Atlantic Books.

Wood, D. 1991. *The Power of Maps*. New York: Guilford Press.