An integrated evaluation of the terrain in a portion of the Missouri River Basin, Iowa-Nebraska

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ABSTRACT

The objective of this study is to determine the effectiveness of an integrated terrain evaluation method as a tool for land-use planning in the United States. It is hypothesized that this method has distinct advantages over the non-integrated methods in use today.

To test the hypothesis, an integrated survey of terrain features is conducted in a portion of the Missouri River basin near Omaha, Nebraska. The survey begins with a reconnaissance-level examination from SKYLAB photographs in natural color and color infrared. Next, tentative boundaries are drawn to differentiate the terrain into land-systems that represent characteristic and recurring patterns of soils, landforms, geologic deposits, and vegetation. The land-system boundaries are refined by interpreting aerial photographs, topographic maps, and the results of field investigations. Finally, an appraisal is made of each land-system to determine suitabilities and constraints for various land-uses.

From this survey, it is evident that the integrated land-system method is a rapid, cost effective, reconnaissance-level tool for evaluating the terrain characteristics of regions and is applicable to metropolitan areas. The
results are easily compiled into a format that is simple, concise, and readily understandable by the non-technical decisionmaker. The integrated methodology warrants more consideration as a tool for land-use planning in the United States.
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A prerequisite for sound land-use planning is adequate information on terrain characteristics such as soil types, geologic materials, topography, vegetation, and water. Knowledge of these characteristics enables land-use planners to determine the nature and extent of resources to be conserved and hazards to be avoided or mitigated. For example, prime agricultural lands and environmentally sensitive areas often should be protected from urban activities. Likewise, urban development should not be exposed to serious hazards such as floods and landslides. At the same time, certain terrain types are well suited for residential subdivisions, highways, industrial complexes, or other developments.

Land-use planners use a variety of methods to acquire terrain data. A common practice is to conduct detailed inventories of separate features such as soil types, geologic deposits, and vegetation. The resulting information is evaluated in terms of suitabilities and constraints for various types of urban development. This approach, used widely in the United States, satisfies the needs of most planning
agencies but, nonetheless, appears to have certain dis-
advantages. First, separate inventories are generally too
detailed and time consuming for reconnaissance applications.
Second, terrain data acquired from separate surveys are
often difficult to correlate because of differences in
scale, mapping technique, and terminology.

The present study examines an integrated method of
acquiring and evaluating terrain data. It is hypothesized
that this method is more effective than separate inventory
techniques in (1) conducting reconnaissance-level surveys
of terrain characteristics and (2) providing terrain data
in a consistent and easily understood format.

**Terminology**

The definitions given below are consistent with those
most commonly used in geographic literature and apply to
the use of the terms in this paper.

**Terrain**

Terrain is the physical land surface and includes
naturally occurring, substantive features known as "land
resources" or "terrain components." These include soils,
geologic deposits, landforms, vegetation, and surface water.
Descriptive terms such as "slope" and "relief" refer to the
character of these components and, as such, are not terrain
components themselves.
Terrain Evaluation

Terrain evaluation is the scientific study of the physical land surface, with particular emphasis on describing the character and distribution of terrain components. Usually, such study involves three steps: analysis, classification, and appraisal (Mitchell, 1973).

Physical-Geographic Regionalization

Physical-geographic regionalization is the classification of terrain into regions based on physical criteria. This manner of classification is used quite often in terrain evaluation.

Landscape

A landscape is a portion of the earth's surface that displays a characteristic association of natural and cultural features.

Landscape Science

Landscape science is the study of the origin, evolution, and structure of landscapes.

Planning Agency

A planning agency is a tax-supported organization that devises long-range plans and/or management programs for land-use, environmental quality, and resource conservation. Examples of planning agencies in the vicinity of the study area are the Papio Natural Resources District,
the Southwest Iowa Soil Conservation District, and the Omaha-Council Bluffs Metropolitan Area Planning Agency (MAPA).
CHAPTER II

LITERATURE REVIEW

A considerable amount of research has been devoted to the subject of terrain evaluation. Contributions have come not only from the discipline of geography, but also from related fields such as geology, hydrology, pedology, climatology, botany, and ecology. In addition, studies on the practical uses of terrain evaluation have been conducted in the applied disciplines including agriculture, forestry, civil and military engineering, and urban and regional planning. This diversity is reflected in the literature, which contains numerous examples of terrain classification schemes, regional landscape surveys, and theoretical discussions on physical-geographic regionalization.

Most of the research and published documentation concerning terrain evaluation has originated since the end of the last century, particularly during the last twenty years. The subject has been studied widely in the Soviet Union, Australia, Great Britain, and Canada. In fact, the study of terrain has attained the status of a formal discipline in the Soviet Union. In other countries, such as the United States, the development of terrain
evaluation methods has been relatively slow, especially with regard to integrated surveys. Correspondingly, the literature produced in various countries differs widely in degree of sophistication and volume.

**Australia**

Much of the pioneering research on terrain evaluation was done by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Melbourne, Australia. Beginning in 1946, the CSIRO conducted a series of integrated terrain surveys in Australia and New Guinea to provide a systematic and comprehensive inventory of the land resources in sparsely settled, unproductive territories.

Since the surveys were to be conducted at the reconnaissance level, conventional methods of terrain classification and description were ruled out as being too detailed and inefficient. The conventional soil survey, for example, was time consuming and expensive. Moreover, such a survey did not fully describe the relationships and associations between terrain components. Recognizing the need for a more suitable approach, the CSIRO devised the land-system method of terrain evaluation. Using high-altitude aerial photos, large territories could be divided into similar terrain types, or land-systems, each of which displayed a characteristic association of soils, landforms, and vegetation. The method provided a quick and inexpensive
means of evaluating hundreds of square miles of terrain at one time.

The land-system surveys of the CSIRO continued from 1946 to 1974 and covered over one-million square miles in Australia and New Guinea. The survey results were published in at least 30 technical reports constituting the "Land Research Series." The first of these reports, Survey of Katherine-Darwin Region, 1946, was a landmark in the history of integrated resource surveys (Christian and Stewart, 1953). It provided a detailed account of the first organized attempt to conduct a regional land-system survey. It also provided a model upon which all subsequent Land Research Series reports were based. An excellent example of a more recent report is Land Research Series No. 30, Lands of the Aitape-Ambunti Area, Papua New Guinea (Haantjens, 1972).

The most recent literature from the CSIRO indicates a phasing-out of the land-system concept in favor of more sophisticated, detailed methods. The prevailing attitude of the organization is that "simple regional surveys such as ours have had their day and have little to offer for more closely settled areas" (Galloway, 1975). The newly formed Division of Applied Geomechanics at CSIRO is now exploring a new method of integrated survey known as "pattern-unit-component-evaluation" (PUCE). The PUCE method utilizes modern techniques of geological engineering.
and geomorphology to classify and describe terrain (Grant, 1973, 1975). The classification scheme is based upon a quantitative analysis of terrain characteristics. Among the factors considered are relief amplitude, drainage density, slope geometry, and soil class, all of which are determined from field measurements. Descriptive information on rock type and plant species is also used. After an assessment of these properties is made, the terrain is classified into units that, like land-systems, display a characteristic association of components. Unlike the land-system method, however, the FUCE approach is based on a rigorous application of engineering principles. A series of reports on the FUCE program began in 1973 and is still underway. The highly technical nature of these reports make them useful to geological and civil engineers in the design of construction projects.

The research and literature of the CSIRO represent significant contributions to the field of geography and, in particular, to the science of terrain evaluation. Of course, a major contribution was the development and refinement of the land-system methodology itself. Furthermore, the survey results provided a wealth of useful information on the character, distribution, and interrelationships of land resources. Finally, the work of the CSIRO represented a major advancement in the coordination and standardization of multidisciplinary research. The
entire survey effort was the integrated product of soil scientists, geologists, botanists, and physical geographers.

**Great Britain-Africa**

The land-systems work conducted by the CSIRO stimulated further research and applications in other countries, notably Great Britain and Africa. The land-system method was adopted by the Land Resources Division (LRD) of the Overseas Development Administration in England. The LRD published several reports on the land-systems of such countries as Bechuanaland, Nigeria, and Gambia (Ministry of Overseas Development, 1970). The purpose of the LRD program was to assess the potential for agricultural development and the extent of natural resources.

An approach similar to that of the CSIRO was taken by Young (1969) in his natural resource survey of Malawi. A British geomorphologist, Young used terrain units analogous to land-systems to classify land into natural resource regions. He strongly supported the use of geomorphological criteria as the primary basis for classification. Thomas, another British geomorphologist, applied the same approach to territories in Africa (Thomas, 1969).

A great deal of study on the military applications of the land-system method has been conducted by the Military Engineering Experimental Establishment (MEE) in Christchurch, England. MEE used the method to supply information on terrain conditions for civil engineering projects
and strategic planning. Working in collaboration with the Soils Laboratory at Oxford University, MEXE was first to conceive a system for predicting terrain conditions over unknown territories by using an automated terrain information system (Mitchell, 1973). The system was used to store and classify detailed terrain data from field surveys. A series of statistical manipulations would then be conducted to identify "recurring landscape patterns," or land-systems. By searching for analogous patterns in unknown, hostile, or inaccessible territories (from aerial photographs and climatic records), predictions of terrain conditions could be made for military purposes. The added capabilities of electronic data processing made it possible to store, classify, and analyze very large quantities of terrain data. MEXE has successfully applied its automated prediction system to a number of areas in England and later in Uganda (Ollier et al., 1969). An excellent summary of the projects undertaken by MEXE is provided in MEXE Report No. 1123, A Review of Studies on Terrain Evaluation (Beckett and Webster, 1969).

The research conducted by MEXE was highly significant from three aspects. First, it demonstrated the value of the land-system method as a scientific basis for prediction. Second, it made a significant advancement in the application of quantitative techniques to the study of terrain. Finally, it further demonstrated the potential
of the land-system method as a useful planning tool. Although the emphasis was on military planning, MEXE did realize the method's potential for land-use and agricultural planning (Ollier et al., 1969).

Canada

Concurrently with the development and use of land-system surveys in Britain, similar efforts were being made in Canada under a program known as the Canada Land Inventory (CLI). This was a governmental program to conduct reconnaissance-level assessments of the land resources and development potential of vast, sparsely settled territories in Canada. As with the CSIRO, the survey results were to provide a basis for economic development and land-use planning by the government. The CLI, however, put an increased emphasis on inventories of wetlands, water resources, forestry, and wildlife. Pilot land-system surveys, modeled after those of CSIRO, were conducted in parts of Newfoundland, Quebec, Manitoba, Saskatchewan, and British Columbia (Lacate, 1969). Data on land-systems were stored in an automated geographic information system with computer-mapping capabilities (Canada Land Inventory, 1970). This system provided a great deal of speed and flexibility in producing computer-generated maps of various terrain features (Mitchell, 1973). In this regard, the Canadian research has made particularly noteworthy achievements.
Soviet Union

In 1950, landscape science emerged as a formal branch of Soviet physical geography, largely due to the pioneering work of V. V. Dokucheyev (1846-1903). He was unquestionably the most influential scholar in the development of the discipline, establishing a paradigm that called for the integrated study of the whole. One must "...honor and study the one, whole and indivisible nature are not its fragments" (Dokucheyev, as translated in Isachenko, 1973). He studied the spatial arrangement of diverse natural and cultural phenomena on the earth's surface. These phenomena, he believed, formed a mosaic of discrete regions on the landscape. This concept of regional study strongly influenced Dokucheyev's followers and remains today as a distinctive trait of Soviet geography (Isachenko, 1973).

It is evident in the literature that the Soviets have adopted a rigorously scientific and comprehensive approach to terrain evaluation. Not only have they considered the basic components of the land (soils, landforms, etc.), but they have focused upon the genetic basis of physical-geographic regionalization. Since this has involved the physical laws of energy transfer at the earth's surface, the Soviets have given due consideration to the problems of heat and water balance, solar radiation, and tectonic forces within the earth's interior. Of course,
this has led to a multidisciplinary approach to landscape science in Russia. During the 1970's, Soviet scientists of many related disciplines have pooled their efforts in an attempt to provide synthesis and unity to regional study in their country (James, 1972).

The research efforts of the Soviets have not been without purpose. The ultimate objective of landscape science has always been to provide a sound basis for planning and resource management. Scientists in that country have used "landscape maps" (analogous to land-systems maps) for soil conservation, pasture management, crop productivity, drought control, reclamation of wetlands, natural resource planning, environmental management (air and water quality control), and urban land use planning (Isachenko, 1973).

In summary, the Soviet tradition in landscape science has emphasized a complex theoretical base and an integrated, highly scientific approach in studying the earth's surface. Among the major Soviet contributions have been a clarification of the scientific basis for physical-geographic regionalization and a demonstration of the practical values of landscape science.

United States

Integrated terrain surveys have received minimal support and use in the United States. A reason for this may
have been the lack of a well defined need for such surveys in this country. It has been suggested that the vigorous survey program of the Soil Conservation Service has precluded this need (Bailey, 1977). Another reason may have been the prevailing attitude in the United States that the landscape should be approached on a component-by-component basis rather than on a integrated, regional basis (Whittlesey, 1954).

An example of the traditional approach to terrain evaluation in this country is provided by the Michigan Land Economic Survey. This survey, conducted in the 1920's, consisted of detailed inventories of soil types, slopes, drainage patterns, vegetative cover, and land-use, each of which was mapped separately (Davis, 1969). Later, when the maps were compared, it was evident that these characteristics formed recurring and predictable patterns on the landscape (DeVries, 1928). On the basis of these patterns, certain natural land-types could be identified. Similar results were produced by the 1933 Montfort Study in southwestern Wisconsin (Finch, 1933). Neither of these studies, however, were truly integrated since the survey data were collected originally on a component-by-component basis.

It was not until 1972 that an attempt was made to conduct an integrated survey of land-systems in the United States. The survey was initiated by the Intermountain Region of the U. S. Forest Service, which has adopted the
land-system method for use in planning and managing forest resources (Wertz and Arnold, 1972). The first survey report, published in 1975, describes the land-systems of the Boise National Forest in Idaho (Wendt et al., 1975). Included in this report is a map of the survey area showing land capability ratings for the various land-systems. These ratings provide useful information on timber, forage, water, and wildlife potentials and go one step beyond the purely descriptive land-systems maps of the CSIRO, MEXE, and others.

Another approach to integrated terrain evaluation has been taken by Bailey, also of the U. S. Forest Service. He classified the United States into a hierarchial order of ecoregions, each of which is characterized by a distinct association of natural features (Bailey, 1976). The criteria used in the classification include biotic properties (types of flora and fauna) and abiotic properties (climate, soils, and landforms). The purpose of the classification scheme and resulting map is to provide a standardized, general framework for more detailed attempts at terrain classification. Of course, Bailey produced this map from a synthesis of existing studies and did not conduct an actual survey.

The Soil Conservation Service, or SCS (sister agency to the U. S. Forest Service, both belonging to the U. S. Department of Agriculture) has developed a land-capability
classification for agriculture which resembles the land-system method. According to the SCS system, land is classified into capability "units" and "classes" on the basis of physical soil properties, relief characteristics, drainage, and climatic conditions. Each capability unit or class represents a uniform combination of physical properties requiring a certain degree of conservation and management to maintain crop production. A detailed account of the SCS system is provided by Klingebiel and Montgomery (1961).

The studies of the U. S. Department of Agriculture represent a significant and very recent departure from tradition in this country. This is particularly true of the land-systems research of Wendt, Wertz, Arnold, and others, who strongly believe that integrated survey methods are worthy of more serious consideration in the United States (Bailey, 1976).

**Summary**

Research in terrain evaluation has followed two distinct trends. The trend of integrated study has emphasized the associations and relationships between features on the earth's surface. Research in this tradition has been confined largely to Russia, Australia, England, and Canada. The other trend has developed primarily in the United States, where studies have focused on the component elements of the terrain. Although recent land-system surveys in the western
United States signal a departure from this trend, integrated methods of terrain evaluation are not widely accepted in this country. No such method has been used for planning applications in urban areas of the United States, including the study area.

The present study follows the tradition of integrated surveys and is patterned closely after the Land Research Series of the CSIRO. Unlike the agricultural emphasis of previous studies, however, the present research is directed at providing terrain data for urban land-use planning.
CHAPTER III

DEFINING AND EVALUATING LAND-SYSTEMS
OF THE STUDY AREA

Study Area

The area of study for the present research extends for about 27 miles (43.5 km) along the Missouri River and includes portions of eastern Nebraska and western Iowa (Figure 1). The central part of the study area includes Council Bluffs, Iowa and the eastern section of Omaha, Nebraska. To the north, the study area becomes predominantly rural in nature and is accentuated by several agricultural communities such as Fort Calhoun and Crescent. The mix of urban and rural environments in the study area provides an interesting setting for examining various land-uses in relation to terrain types.

Applying the Land-system Method to the Study Area

In evaluating the terrain of the study area, the author used the land-system method because it appeared to be the most straightforward and thoroughly documented of the integrated methods. The procedure used to define land-systems consisted of five steps: 1) preliminary physical-geographic overview, 2) photographic reconnaissance and tentative land-systems delimitation, 3) field investigation,
Figure 1. Base map showing the study area and surrounding territory.
Step 1: Preliminary Physical-Geographic Overview

The purpose of this step was to become familiar with the overall "lay of the land" and climatic setting of the study area before commencing more detailed analysis and field work. The required information was obtained from published soil surveys, geologic reports, climatic records, and other sources.

Physiography

The study area lies near the western edge of the Central Lowland physiographic province, a predominantly glaciated area of relatively low relief occupying the central United States (Hunt, 1974). Locally, the physiography is characterized by gently rolling glacial drift hills that are capped with deposits of wind-blown silt (loess). This type of landscape is known as a "broad loess-mantled upland till plain" (Miller, 1964). Within the study area, the Missouri River has eroded a broad, nearly level floodplain into the till uplands. In some locations, this plain is bordered by conspicuous, steeply sloping bluffs and heavily dissected hills (Figure 2).
Figure 2. Generalized physiography of the study area and surrounding territory.

Lithology

The surface deposits of the study area are dominated by loess, which reaches a thickness of over 100 feet (30.5 m) in some locations (Miller, 1964). Other surface deposits include floodplain alluvium, terrace alluvium, alluvial fan deposits, and slope wash, all of Quaternary age (Figure 3). Below this unconsolidated mantle lie bedrock formations of limestone, shale, and sandstone (Miller, 1964).

Climate

The study area is situated in a transitional climatic zone between the predominantly humid eastern United States and the semiarid climates of the West (U. S. Department of Commerce, 1975). The climate in this zone is continental with relatively warm summers and cold, dry winters (U. S. Department of Commerce, 1975). Historical records of weather data collected at Omaha show that the warmest months are July and August, when temperatures average 77.4°F (25.2°C) and 75.1°F (23.9°C), respectively (U. S. Department of Commerce, 1975). January, the coldest month, averages 22°F (-5.6°C). The average annual precipitation in the study area is 28.5 inches (72.3 cm), most of which falls during sudden showers or thunderstorms from April to September, the growing season. This particular climatic setting is quite favorable to agricultural production, since ample moisture is usually provided to crops when it is needed most, during the warmest months.
Figure 3. Generalized surficial geology of the study area and surrounding territory.

Source: Miller, 1964; aerial photographs.
Soils

The study area lies in the prairie soil (or brunizem) zone of the United States. These dark colored, extremely productive soils are typical of the subhumid grasslands of the prairie (Hunt, 1972). The prairie soil zone represents a transition from the predominantly acid soils of the humid eastern United States to the more alkaline soils of the semiarid West.

Within the study area there are several major groups, or "associations", of prairie soils (Figure 4). A soil association is defined as a portion of terrain that has a distinctive proportional pattern of soil types (Soil Conservation Service, 1975a). Two major types of soil associations are found in the study area: the upland type, forming on loessal parent materials; and the bottomland type, occurring on the alluvial deposits of floodplains (Soil Conservation Service, 1975a, 1976). The upland soils are generally deep, well drained, medium to moderately fine textured loams. The bottomland soils vary widely in texture and drainage.

Natural Vegetation

The study area lies in a broad belt of tall grass prairie vegetation extending from North Dakota south to Texas. This belt marks the gradual change from the eastern deciduous forest to the steppe and desert plant communities that dominate the western plains areas of the United States.
Figure 4. Major soil associations of the study area and surrounding territory.

Vegetative communities within the prairie vegetation belt can assume varying proportions of forest and prairie flora, depending on local environmental conditions (Figure 5). Crop cultivation and urbanization have destroyed much of the native vegetation in the study area.

**Step 2: Photographic Reconnaissance and Tentative Land-systems Delimitation**

The objectives of this step were to collect general terrain information and to define tentative land-systems. Both tasks involved considerable use of two SKYLAB photographs, one of which was in natural color (Figure 6) and the other in false-color infrared (Figure 7). Both were photographed in June 1973 at an altitude of 270 miles (436 km). These particular photographs were selected for several reasons. First, they provided synoptic views of the entire study area. Second, the photographic resolution was remarkably good, despite the small scale. Third, using two types of photography provided different spectral "views" of terrain features. For example, the natural color photograph was particularly well suited for the identification of landforms, surface relief, and dissection patterns formed by tributary streams. The false-color infrared photograph was more useful for locating dense vegetative cover (the bright red and dark red tones in Figure 7) and bare ground (the light blue areas in Figure 7).

Using both photographs, the author delineated tentative
LEGEND

- Flood plain forest and prairie: dominated by willow-cottonwood association, canary grass, cord grass
- Eastern deciduous forest: oak-hickory association dominates.
- Tallgrass bluestem prairie: bluestem, switch grass, Indian grass dominate.

Figure 5. Potential native vegetation zones in the study area and surrounding territory

Source: Kaul, 1975; MAPA, 1978c.
Figure 6. SKYLAB natural color photograph illustrating tentative boundaries of land-systems A and B. The numbers refer to three selected ground observation points (discussed later in this chapter). For reference, the outlines of the base map (Figure 1) and the study area are annotated on the photograph.
Figure 7. SKYLAB false-color infrared photograph of the study area and surrounding territory
land-systems by identifying characteristic and recurring patterns in signature (color, tone, texture, etc.). Approximate land-system boundaries were plotted first on the photographs and then transferred onto topographic working maps (1:250,000). During this transfer, it was possible to refine the boundaries using the relief, landform and vegetation information on the topographic maps.

Next, the author examined aerial photos (stereoscopically) for selected locations along land-system boundaries. This made it possible to further refine the boundaries, especially in areas where complex landscapes made boundary definitions difficult. The stereoscopic photographs were in the conventional, black-and-white format at a scale of 1:20,000.

A reasonable degree of precision was attained by constantly readjusting the boundaries between the SKYLAB photographs, the topographic map, and the conventional aerial photographs. This procedure resulted in the definition of two land-systems, annotated by "A" and "B" (Figure 6). At this stage, the configurations of the land-systems were not final, since verification in the field had not been completed.

The interpretations made from the SKYLAB and conventional aerial photographs included preliminary physical descriptions of each land-system. For example, Land-system A was identified as an alluvial complex with river-deposited
sediments, nearly level topography, and a general lack of dense tree cover. Alluvial landforms such as meander scars and oxbow lakes were commonly observed on the photographs. In addition, the presence of extensive crop cover suggested productive soils and adequate moisture conditions. In many areas near the Missouri River channel, the crop pattern appeared to become somewhat irregular and much lighter in tone. Evidently, these areas contained recently deposited, immature, sandy soils and poorly developed vegetation. These conditions were well represented by the SKYLAB photographs (refer to the northern portion of the Missouri River floodplain, near the river channel, Figure 6). Away from the river channel, the alluvial soils appeared somewhat darker in tone, perhaps due to higher clay or loam content.

The SKYLAB photographs indicated that the terrain of Land-system B was radically different from that of the alluvial complex. The very dark photographic tones of this land-system suggested a dense tree cover accompanied by a heavily dissected, rugged topography. It was also apparent that Land-system B was much more extensive and better developed on the Iowa side than on the Nebraska side.

Step 3: Field Investigation

The author's method of field investigation consisted of observing key points along selected traverse lines,
a method recommended by Christian and Stewart (1953). The observation points and traverses were selected beforehand from the SKYLAB photographs and topographic maps. In designing the field plan, the author considered such factors as terrain complexity, uncertain boundaries and features, adequate sample size, and accessibility. The locations of the ground observation points and traverses are shown in Figure 8 (also see Figure 6).

At each ground point, the author collected detailed data on soil types, geologic deposits, landforms, and vegetation. The key to identifying land-systems was to note characteristic and recurring patterns displayed by these components. A change in pattern signified a land-system boundary. By establishing ground truth with respect to the SKYLAB photographs, the land-system boundaries could be traced using only a limited number of cursory field checks. The only boundary that remained uncertain was that passing through Omaha, where the concentration of urban features made boundary placements difficult.

To assist in differentiating land-systems in the field, the author used various maps published by the Soil Conservation Service, U. S. Geological Survey, and the Omaha-Council Bluffs Metropolitan Area Planning Agency (figures 9 through 12).

The photographs in figures 13 through 20 will help illustrate how each land-system was identified and described
Figure 8. Locations of ground observation points and field traverses in the study area
Figure 9. Topographic detail of a portion of the study area, Mills and Pottawattamie counties, Iowa. Note the contrast in relief between land-systems A and B. The contour interval is 10 feet. (This figure is used as a base map for the next three illustrations.)

Figure 10. Portion of a slope map of a selected area in Mills and Pottawattamie counties, Iowa. Slopes exceeding 17% are common in Land-system B, while Land-system A is relatively flat.

Figure 11. Portion of a detailed soil survey map of a selected area in Mills and Pottawattamie counties, Iowa. The contrast between soil patterns in land-systems A and B is apparent. The numbers refer to soil types (see MAPA, 1978b).

Figure 12. Portion of a vegetation map of a selected area in Mills and Pottawattamie counties, Iowa. Dense tree stands are common in Land-system B, in contrast to the scattered tree cover of Land-system A.

Source: MAPA, 1978c.
in the field. Figures 13 and 14 show the distinct appearance of Land-system A at ground observation point 5. As determined from the soil survey map (Figure 11), the soils are of alluvial origin and display a highly irregular pattern on a level surface. Several soil types are high in clay content, resulting in low permeability and poor drainage (Figure 15). Natural vegetation at this location consists mostly of scattered willow and cottonwood tree cover. Cottonwoods are particularly common in several areas of active slope-wash deposition (Figure 16). Characteristic geologic features include local concentrations of alluvial sand and clay in abandoned river channels, (Miller, 1964). As seen from SKYLAB, the overall appearance of the terrain at this location is characterized by a relatively uniform texture with gradual tone changes (refer to ground observation point 5 on Figure 6).

The overall appearance of Land-system B is strikingly different from that of the previous land-system. The most obvious differences are in physiography and vegetation (Figure 17). Distinctive physiographic features of this land-system include nearly vertical cliffs, sharply crested ridges, terracettes, and steep sideslopes, all of which portray a heavily dissected, rugged terrain (Figure 18). The entire land surface is comprised of loess, which is often heavily eroded (Figure 19). Most of this land-system is thickly wooded with oak, hickory, dogwood, and other
Figure 13. Land-system A. At this point, the land system is about 4 miles (6.5 km.) wide, terminating at the bluff line on the horizon. (Location: ground observation point 5, viewing west.)

Figure 14. Elevated view of Land-system A. The "table-top" plain is abundant with crops. Scattered rows of trees (cottonwood) border the crop fields. (Location: ground observation point 6, viewing west.)
Figure 15. Cottonwoods occurring along the flood plain margin of Land-system A. These trees were observed in association with disturbed soil conditions resulting from the deposition of sediments from nearby foot slopes. (Location: ground observation point 6, viewing west.)
Figure 15. Standing water, a common occurrence in Land-system A. The cause is poor soil drainage. Note the abandoned river terrace (arrow 1) and man-made levee (arrow 2). (Location: ground observation point 21, viewing southwest.)
Figure 17. Abrupt change in terrain from Land-system A (foreground) to Land-system B (in distance). Note in particular the contrast in vegetation and physiography. Also, note the dark, waterlogged soils between crop rows, a typical condition of poor soil drainage in Land-system A. (Location: ground observation point 5, viewing southeast.)
Figure 18. Characteristic terrain features of Land-system B. The steep slopes are covered with well developed terracettes, or "cat steps," formed by repeated slippage and downslope movement of loess. Native grasses are abundant on the upper slopes. Trees and shrubs occupy the drainage ways. (Location: ground observation point 6, viewing southwest.)
Figure 19. Gully erosion in Land-system B. The gulley is about 10 feet (3 meters) deep, providing an exposure of light brown/tan loess. (Location: ground observation point 6, viewing east.)

Figure 20. Dense tree cover in Land-system B. (Location: ground observation point 6, viewing north.)
varieties of trees and shrubs (Figure 20). On the SKYLAB photographs, this vegetative cover and rugged topography appear nearly solid black (Figure 6) or very dark red (Figure 7).

**Step 4: Final Land-systems Mapping and Summary Descriptions**

The final land-systems map (Figure 21) was constructed after having made the necessary boundary adjustments in the field. Table 1 compares the physical properties of each land-system and represents a synthesis of the data collected from existing reports, the aerial photographs, and the author's field investigations. Finally, the block diagram in Figure 22 depicts the areal relationships of the various terrain components in land-systems A and B.

**Step 5: Land-system Appraisals**

Each land-system was appraised in terms of its suitabilities and constraints for various land-uses. The appraisals were based on the author's field data, supplemented by engineering test data and land-use suitability ratings from the Soil Conservation Service (1964, 1975a, 1976, 1977). Particular attention was given to potential natural hazards, possible environmental degradation from urban development, natural resource supplies, and environmentally sensitive areas. The end result of this process was a matrix of land-use suitability ratings for each land-system (Table 2). Explanations of these ratings follow.
Figure 21. Final land-systems map of the study area showing results of boundary refinements.
Table 1. Comparison of physical properties for land-systems A and B

<table>
<thead>
<tr>
<th>Physiography:</th>
<th>Land-System A: Missouri River Alluvial Plain</th>
<th>Land-System B: Dissected Loess Hills and Bluffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level valley floor, alluvial terraces and fans, meandering river channel with abandoned cut-offs (oxbow lakes) and meander scars.</td>
<td>Rugged, strongly dissected loess hills and massive bluffs. Hills are sharp-crested with steep side-slopes and terracettes. Bluffs nearly vertical in places. Intricate drainage patterns, deep gullies.</td>
<td></td>
</tr>
<tr>
<td>Relief and Slope:</td>
<td>Very slight. Slopes less than 1% (0-½ degrees).</td>
<td>Strong relief. Slopes generally 30% to 100% (17 - 45 degrees).</td>
</tr>
<tr>
<td>Surface Geology:</td>
<td>Fine to coarse textured, unconsolidated alluvium (flood plain, terrace, alluvial fans); slope wash (minor). Various amounts of clay, silt, sand, and gravel. Quaternary age.</td>
<td>Fine textured, unconsolidated loess; slope wash (minor), terrace alluvium (minor - found in small tributary valleys).</td>
</tr>
</tbody>
</table>

(continued on next page)
<table>
<thead>
<tr>
<th>Natural Vegetation:</th>
<th>Land-System A: Missouri River Alluvial Plain</th>
<th>Land-System B: Dissected Loess Hills and Bluffs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Willows and cottonwoods in scattered cover. Some native grasses (bluegrass, prairie cordgrass, reedgrass). None very extensive.</td>
<td>Oak, hickory, elm, dogwood, hackberry, mostly in closed cover. Some open prairies with big bluestem and little bluestem.</td>
</tr>
</tbody>
</table>

Figure 22. Typical arrangement of terrain components in land-systems A and B.

Sources: Soil Conservation Service, 1975a, and author's field data.
<table>
<thead>
<tr>
<th>Proposed Use</th>
<th>Overall Suitability Rating(^1)</th>
<th>Land-System A</th>
<th>Land-System B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban Uses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dwellings</td>
<td>•</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Commercial</td>
<td>X</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Industrial</td>
<td>X</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>X</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td><strong>Open Space and Recreational Uses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Preservation Areas</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Recreation</td>
<td>O</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Agricultural Uses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop land</td>
<td>X</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Pasture land</td>
<td>O</td>
<td></td>
<td>•</td>
</tr>
</tbody>
</table>

\(^1\) Based on author's interpretations: not to be used for detailed analyses and site evaluations.

- O = Generally well suited
- X = Marginally suited
- • = Generally poorly suited

Definitions:
- Dwellings - single and multiple family structures
- Commercial - shopping centers, "strip commercial," etc.
- Industrial - manufacturing facilities
- Transportation - highways, roads, airports, etc.
- Envir. preserv. areas - wildlife habitats, sites of scenic beauty, ecologically sensitive areas, etc.
- Recreation - parks, campgrounds, trails, etc.
- Crop land - actively producing mixed crops
- Pasture land - idle land used for feed, grazing, etc.
Land-system A

The level topography, fertile soils, and ample water supply of Land-system A are particularly well suited for agriculture, natural vegetation, recreation, and open space.

The major constraints for urban development in this land-system include poorly drained and unstable soils, periodic high water tables, and potential flooding hazards. The unfavorable soil and water table conditions can be detrimental to construction projects, foundation stability, and the proper functioning of septic tanks. Flooding could be a major problem if it were severe enough to overflow or damage existing levees. This possibility is particularly important for residential dwellings, thus the "poorly suited" rating for this land-use category. The "marginally suited" rating for commercial, industrial, and transportation land-uses is based on the assumption that flooding is less likely to cause loss of lives in intermittently used areas.

Land-system 3

The rugged, wooded terrain of Land-system 3 provides scenic settings for hiking, parks, camping, and other recreational activities. These conditions are also highly favorable for wildlife habitats, particularly in areas where water is readily available, such as near the Missouri River.
Certain geologic and soil properties in this land-system pose problems for urban development. For example, loess deposits are subject to instability and subsidence when wet and under loads such as foundations. These conditions are particularly acute in steeply sloping areas and can result in extreme instability if the slopes are graded or disturbed by construction (Wayne, 1971). The "marginally suited" rating for dwellings is based on the assumption that isolated areas in Land-system B contain slopes shallow enough for low density housing. For commercial and industrial purposes, however, it is nearly impossible to find sites that are suitably large with level topography and few trees. In general, the same is true for transportation facilities, although some areas are suited for local roads. The agricultural potential of this land-system also is restricted by the rugged topography. Intense conservation measures would be required to prevent soil erosion in steeply sloping areas.
CHAPTER IV

SUMMARY AND CONCLUSION

From this study it appears that the land-system method of terrain evaluation would be highly effective as a tool for land-use planning in the United States. As hypothesized, the method meets certain needs that conventional techniques in this country do not satisfy. One such need is for a rapid, cost effective, reconnaissance-level tool for evaluating the soils, geology, landforms, and vegetation of large territories. When applied to the study area, the land-system method demonstrated this capability quite well. Conventional methods of inventorying separate terrain components are not well suited for reconnaissance purposes because of the extensive time and field data requirements.

The land-system method also satisfies the need for terrain data presented in a simple and unified format understandable to the non-technical decisionmaker. Conventional methods of separate inventory often lack standardization, making it difficult to correlate and summarize the results.

This study also demonstrates that the land-system method is useful for evaluating terrain in urban areas. Although it may be difficult to determine land-system
boundaries in certain highly developed areas, general assumptions on terrain conditions can be made by analyzing surrounding areas and extrapolating boundaries to fit overall landscape patterns. Of course, natural boundaries are always difficult to define in densely settled areas, regardless of the survey method used.

**Recommendations for Further Study**

The land-system method should be tested in other metropolitan areas to determine its applicability under a greater variety of terrain types and planning situations. Hopefully, the present study will provide a useful starting point for such applications.

It is suggested also that future studies explore the use of land-units, which are detailed subdivisions of land-systems. This would open the possibility of a hierarchical classification scheme for terrain. A result may be a greater capability for detailed land-use planning applications.

Since this study used only SKYLAB and conventional aerial photographs, it might be helpful to explore the use of other types of specialized imagery such as radar, thermal infrared, and multispectral scans.
REFERENCES CITED


—, personal communication, 9-10-77.


Bragg, T., personal communication, 12-12-77.


Galloway, R. M., personal communication, 12-20-75.


James, P. E., 1972, All possible worlds: Indianapolis, Odyssey Press, 622 pp.

Kaul, R. E., 1975, Vegetation of Nebraska: Lincoln, Nebraska, Conservation and Survey Div., University of Nebraska, map.


MAHA (Omaha-Council Bluffs Metropolitan Area Planning Agency), 1973a, slope map the the Council Bluffs South Quadrangle.

_______, 1973b, Soils and surficial geology of the Council Bluffs South Quadrangle: map.

_______, 1973c, Vegetation in the Council Bluffs South Quadrangle: map.


Wayne, W. J., 1972, Guidebook for field trip on urban geology in eastern Nebraska; Lincoln, Nebraska Geological Survey, 15 pp.


