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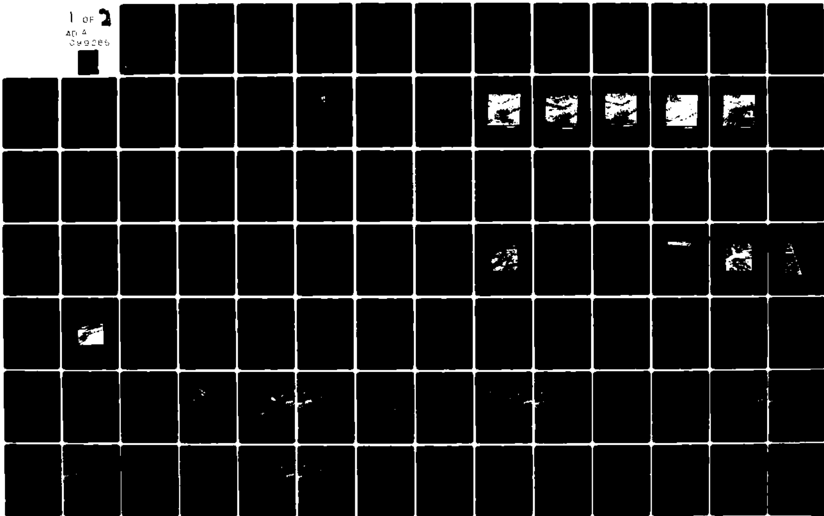

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Satellite imagery can be of very real value to the poorly mapped areas of the world. Because agriculture is dynamic with constantly changing conditions, remote sensing offers the feasibility of monitoring agricultural lands over an extended period of time. The specific objectives of this research are: (1) to estimate the total acreage/hectares of oasis agricultural lands of the Turpan Depression on selected dates from 1972 to 1978, (2) to prepare thematic maps of the oasis agriculture for the years 1972, 1973, 1977, and 1978, and (3) to assess the agricultural land reclamation efforts within this study area.

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This thesis dealt with the mapping of oasis agriculture from Landsat imagery and the associated problems relating to image resolution, and the lack of ground data and supporting information.

USE OF SATELLITE IMAGERY TO MONITOR THE OASIS AGRICULTURE IN THE TURPAN DEPRESSION, XINJIANG UYGUR AUTONOMOUS REGION, PEOPLE'S REPUBLIC OF CHINA--A CASE STUDY

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MAY 1981

By

Dorothy F. Klasse

Thesis Committee:

Everett A. Wingert, Chairman
Jen-hu Chang
John M. Street

We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for the degree of Master of Arts in Geography.

THESIS COMMITTEE

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CHAPTER I

INTRODUCTION

A. Purpose of the Study

Since the launching of the Landsat series of earth resource satellites in 1972, Landsat data have been applied to many environmental problems; providing regular, up-to-date information on various aspects of the earth's surface. Many studies (Erb, 1974; Hass et al., 1975; Westin et al., 1975) have demonstrated the application of Landsat imagery for use in conducting inventories and mapping of various natural resources. Landsat has provided far-reaching opportunities for studies of foreign areas which are not readily accessible, and where accurate, contemporary spatial data are unavailable or difficult to obtain. China is such an area, and the choice of utilizing imagery taken by NASA's Landsat spacecraft was the only viable source from which to conduct the thematic mapping of oasis agriculture. Therefore, this study was undertaken as a feasibility study of Landsat imagery as a mechanism for detecting, identifying, and mapping the oasis agriculture of the Turpan Depression, Xinjiang Uygur Autonomous Region, People's Republic of China* (Figure 1). The Turpan Depression was selected for this study because of its particular physical setting. On color composite imagery, there exists a very high tonal contrast between the oasis agriculture and

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*Note: other spellings for Turpan are: T'u-lu-fan (Tulufan) and Turfan.

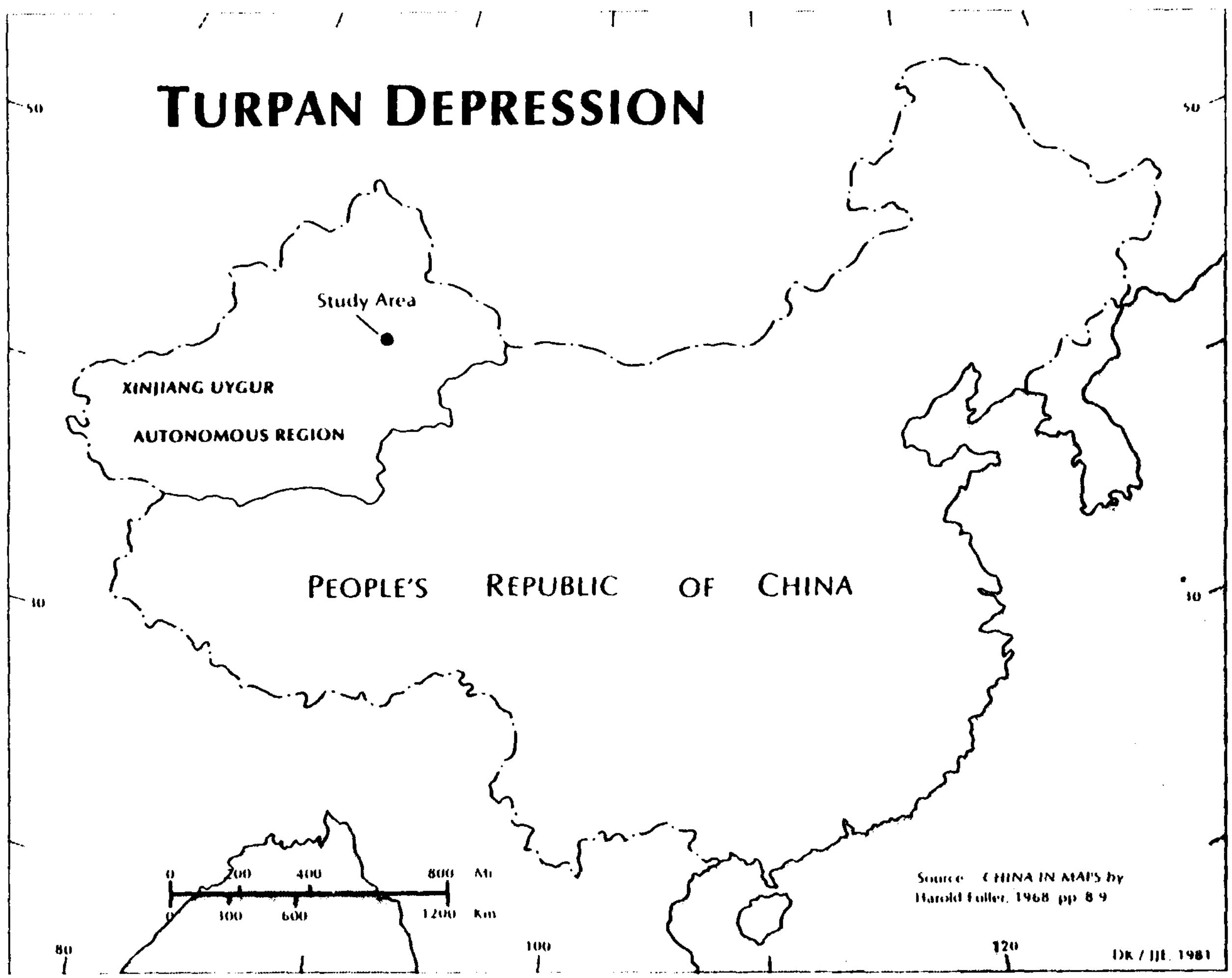


Figure 1. Location of the TURPAN DEPRESSION within the Autonomous Region of Xinjiang Uygur, The People's Republic of China.

the surrounding land features. This characteristic lends itself well to the manual interpretation techniques used in the mapping procedure.

The specific objectives of this study are: (1) to estimate the total acreage/hectares of oasis agricultural lands of the Turpan Depression on selected dates from 1972 to 1978, (2) to prepare thematic maps of the oasis agriculture for the years 1972, 1973, 1977, and 1978, and (3) to assess the agricultural land reclamation efforts within this study area.

This thesis, then, is concerned with the mapping of oasis agriculture from Landsat imagery and the associated problems relating to image resolution, and the lack of ground data and supporting information.

B. Similar Works

Much of the literature concerning Landsat research is available in NASA Symposium Results. Freden and Mercanti (1974) have summarized the Third Symposium in three volumes. The work done in agriculture with Landsat appears under the discipline heading "Agriculture, Forestry and Range Resources." Researchers have employed a variety of interpretation techniques when extracting information from Landsat data such as computer data processing and image enhancement. For the ERTS system in particular (now termed Landsat), Erb (1974), Wigton (1974), Draeger et al. (1974) and Baumgardner et al. (1974) have reported on approaches to crop identification and area measurements that have indicated varying degrees of success. Morain and Williams (1975), using a slightly different methodology also reported successful crop identification and area estimation of winter wheat in southwest Kansas using satellite imagery. An investigation by Mian (1979) shows that great potential exists for using Landsat imagery for the preparation of base maps at a scale of 1:250,000 for those areas where current maps are not available. Application of remotely sensed data for the study of existing land use and changes in land use has been widely recognized. Anderson et al. (1976) dealt with designing a specific classification system for use with remote sensing data and Gaydos et al. (1978) studied land use and land cover of the Puget Sound Region. Two researchers, Welch and Colvocoresses, have investigated the cartographic reliability of Landsat data for mapping. Colvocoresses, in a recent U.S. Geological Survey Publication, ERTS-1 A New Window On Our Planet (1976), concluded that ERTS images are suitable for planimetric mapping since the images under proper condition can meet National Map Accuracy Standards at the scale of 1:250,000.

Thematic maps normally provide information concerning the distribution and areal extent of classes of objects and may be produced without normal concern for specific map accuracy standards. Nevertheless, thematic maps require delineation of class boundaries and depending upon the maps' use, Welch (1973) concluded that ERTS images appear best suited to cartographic applications at scales smaller than 1:500,000.

In a National Aeronautics and Space Administration Publication, The Verification of Landsat Data in the Geographical Analysis of Wetlands in West Tennessee (1978), Rehder and Quattrochi concluded that Landsat imagery is a reliable source for detecting, identifying, measuring and mapping wetlands in West Tennessee. This study further illustrated that image clarity and measurement error are inversely proportional to scale;

i.e., image sharpness decreases at larger scales while the amount of measurement error increases at smaller scales. In another study, Welch et al. (1979) successfully utilized Landsat image data in photographic and computer compatible tape formats to map land use and identify crops in the Nun River basin of northeast China.

These examples of current research illustrate that varying degrees of agricultural information can be detected and mapped with accuracy from Landsat data, depending on the techniques employed in the study. Most of the research examined, however, did not rely principally on manual interpretation techniques for delimiting agricultural boundaries from Landsat imagery.

The choice of using a manual technique for image interpretation was based on the following reasons: (1) even though manual techniques may require more man hours for interpretation, the equipment used, i.e., Bausch and Lomb Zoom Transfer Scope, and a transparent plastic area grid on a 10 to-the-inch cell grid were available and easy to operate and use, (2) cost constraints of the study, (3) skills of the interpreter, and, finally, (4) it was felt that the degree of accuracy acceptable for mapping only one class of information could be achieved through this technique. Therefore, extensive computer analysis and other sophisticated electronic applications to improve mapping quality and accuracy were not considered necessary for this particular study.

C. Landsat and Multispectral Scanner Characteristics

Some of the particular advantages in using Landsat data for this study include the following reasons. (1) Each scene covers such a large area (185 by 185 km) that a synoptic view of oasis agriculture in the

Turpan depression is possible from just one scene. (2) Landsat images are near-orthographic, this implies that Landsat scenes can be superimposed to fit a base map. This particular characteristic was invaluable in this study, as one of the techniques applied in the mapping procedure was the enlargement of the 1:1,000,000 scale imagery to the scale of 1:250,000. (3) Since Landsat passes occur every nine days, the selection of scenes for thematic mapping of the oasis agriculture did not pose a problem. Since vegetation reflects differently in different parts of the electromagnetic spectrum, the use of three of the four MSS bands (4, 5, and 7) when combined to produce a color composite image has the added advantage of portraying the signatures of vegetation in a very bright red color. The chlorophylls in living vegetation reflect heavily in the near-infrared portion of the electromagnetic spectrum. Vegetation, therefore, will produce the "brightest" signature in those wavelengths ranging from .8 to 1.1 micrometers, or in the MSS Band 7. By exposing a sensitized color emulsion through a red filter to these "bright" signatures, vegetation signatures will be reproduced as red on the false-color print.

A complete description of the Landsat system and multispectral scanner characteristics (Figure 2) is given by NASA (1972). A brief summary of some of the features is given below.

Landsat-1 (formerly the Earth Resources Technology Satellite--ERTS-1) was launched on July 23, 1972 and was retired from service on January 6, 1978. Continuity of the Landsat-type coverage is currently being maintained since an identical Landsat-2 was launched on January 22, 1975, and Landsat-3 was successfully launched on March 6, 1978.

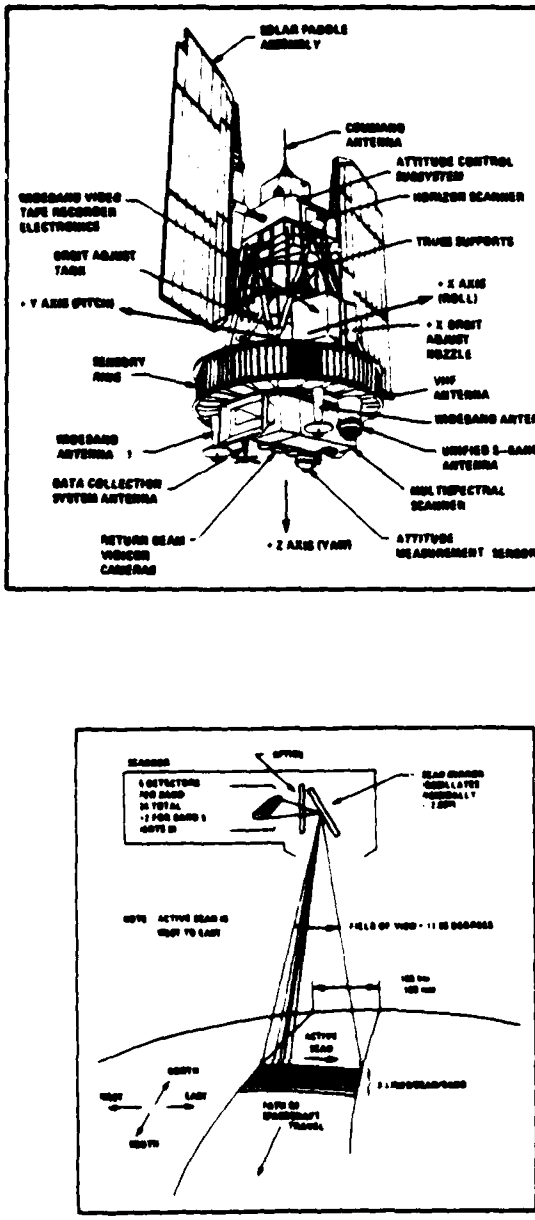


Figure 2. Landsat observatory configuration showing location of MSS (top); and MSSscanning arrangement with respect to the earth's surface (bottom). Source: NASA-User's Handbook.

The Landsat multispectral scanner system employs an oscillating mirror to scan the surface of the earth as it passes beneath the satellite. The MSS systems image scenes in the following wavelengths.

Band 4: 0.5-0.6 micrometers--(green)--emphasizes sedimentation in water and delineates areas of shallow water such as shoals, reefs, or sandbars.

Band 5: 0.6-0.7 micrometers--(red)--facilitates the detection of cultural features in contrast to vegetated surfaces.

Band 6: 0.7-0.8 micrometers--(Red to near infrared)--facilitates the detection of boundaries between land and water, landforms, and species differentiation.

Band 7: 0.8-1.1 micrometers--(near infrared)--provides good penetration of atmospheric haze, and facilitates the detection of the boundary between land and water, land use detail is very indistinct.

Landsat MSS systems collect sunlight reflected from objects on earth in proportion to the sensitivities of each MSS band. The multispectral scanners on the Landsat spacecrafts have capabilities of distinguishing these different wavelengths and frequencies of energy which are reflected by different targets and scenes. Each target, because of the different materials of which it is composed, produces its own characteristic spectral signature, as was previously mentioned regarding green vegetation. Although each MSS band produces images which are of value in themselves, all bands should be consulted for the optimum interpretation of earth features and events. For this particular study, the image product employed was color composite transparencies at the scale of 1:1,000,000 because for manual interpretation it is much easier to perceive differences in color than changes in gray values. The next section will cover the particular materials and equipment used for this study.

D. Materials and Equipment

Success of Landsat imagery interpretation begins with acquiring cloud free or at least less than 10% cloud cover Landsat scenes of the study site. To this end, the EROS Data Center provided two options: (1) to personally view the microfiche of the desired path and row on a display screen for eventual selection, and (2) to provide a detailed printout of the desired path and row with appropriate dates since season was involved as a parameter in this study. Both options were exercised in procuring the best possible Landsat imagery for the mapping of oasis agriculture in the Turpan Depression.

Seven 9" by 9" color composite transparencies as described in Table I were acquired at the scale of 1:1,000,000, all less than 10% cloud cover. The dates for the MSS scenes for the area ranged from October 1972 to May 1978, excluding the winter months of November, December, January, and February. The quality of the imagery varied from scene to scene. Nearly 100% of the study area was covered by each image with the exception of 16 September 1977 which covered a little less than 50% of the study area due to satellite path alignment.

Following examination of all imagery, it was determined that two of the scenes, 15 October 1975 and 28 October 1976 would not provide enough contrast for the delineation of the oasis agriculture and were excluded from the study. May 27th, 1978 image was also considered as not acceptable, but for this mapping project it was used even though certain portions of the image could not be mapped. See Figure 7 and compare with Figure 3 and notice the areas that have a washed out appearance. These were the areas that could not be mapped because of a

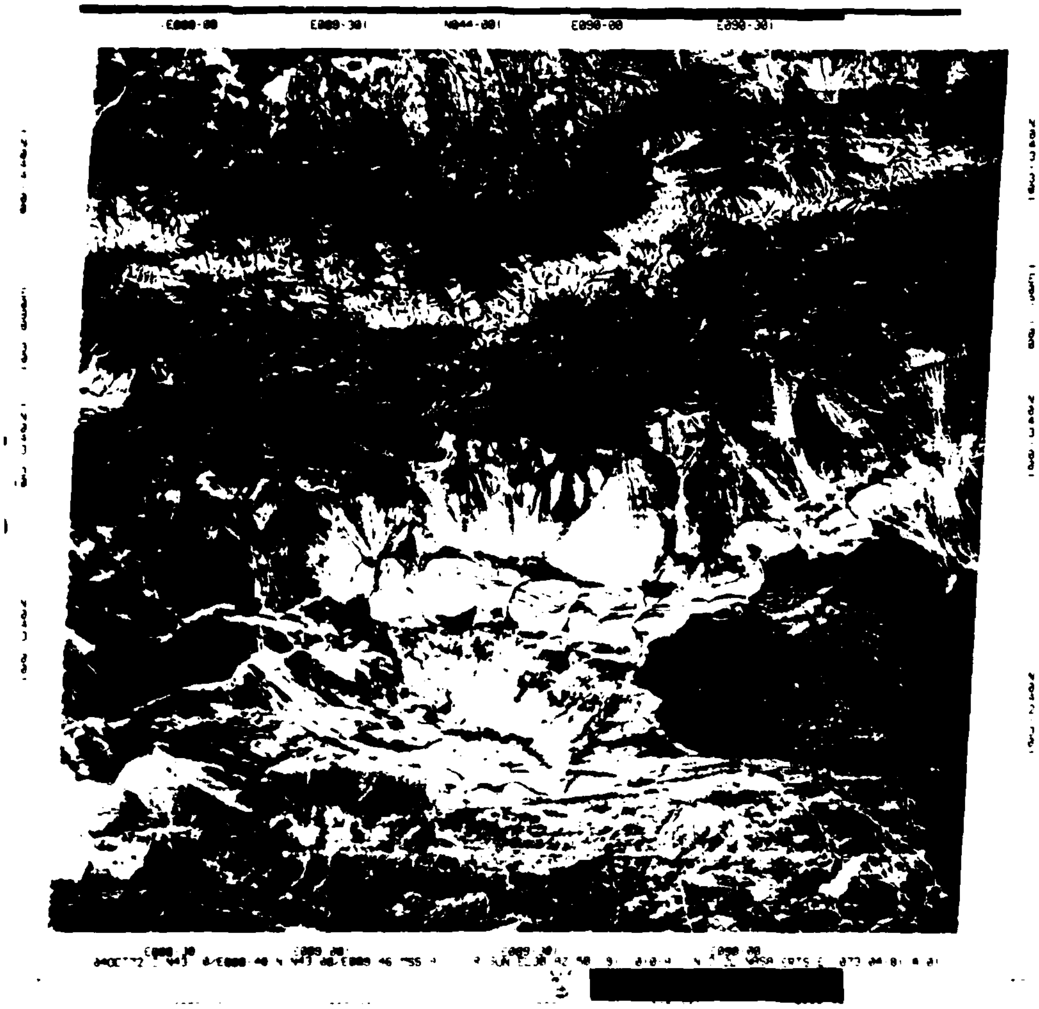


Figure 5. Landsat image # E-1073-04381 taken 04 October 1972

Figure 4. Landsat Image # E-1307-04185 taken 26 May 1973.

Figure 5. Landsat Image # E-2 861-03465 taken 01 June 1977.

Figure 6. Landsat Image # E-2968-03353 Taken 26 September 1977

Figure 7. Landsat Image # E-21221-03434 taken 27 May 1978

TABLE I

LIST OF LANDSAT IMAGERY

Figure No.	Date	I.D. Scene No.	Scale	Quality
3	04-10-72	1073-04181	1:1,000,000	Good
4	16-05-73	1307-04185	1:1,000,000	Good
	15-10-75	2266-03594	1:1,000,000	Fair
	28-10-76	2645-03563	1:1,000,000	Fair
5	01-06-77	2861-03465	1:1,000,000	Good/Fair
6	16-09-77	2968-03353	1:1,000,000	Good
7	27-05-78	21221-03434	1:1,000,000	Fair

high cloud cover. For area measurements, the area grid of 10-to-the-inch cells was used. The transparent grid was placed over the contact paper photographic proof of the negative scribed compilations and then a visual estimate was made of the proportional amount of oasis agriculture in each cell of the grid. At first, an electronic polar planimeter was used but it was found to be not accurate enough for the very small areas to be measured, plus it was much more time consuming. Therefore, the area grid was employed as the instrument used to make all the area estimates.

The Bausch and Lomb Zoom Transfer Scope, an instrument that enables the operator to view two materials in superimposition was employed for the enlarged interpretations at 1:250,000. This instrument can essentially be used as a tracing device which incorporates means for changing scale in the process of compilation. It consists of a zoom magnification mechanism which provides rapid, accurate matching of photo scale to data-base scale. The 1:1,000,000 scale imagery was enlarged to 1:250,000 scale using this instrument.

Four topographic maps; sheet numbers NK46-4 and NK46-1, printed in 1972 by the U.S. Army Topographic Command, Washington, D.C. and sheet numbers NK45-3 and NK45-6, printed in 1973 and 1978 by the Defense Mapping Agency Topographic Center, Washington, D.C. at the scale of 1:250,000 were used as the base maps from which the scale stable cronoflex prints were made. All the oasis agricultural areas were drawn on Stabilene drafting film and registered to these cronoflex positives.

In summary, the mapping of oasis agriculture in the Turpan Depression from Landsat color composite transparencies, enlarged to 1:250,000 was done by manual interpretation techniques without ground truth and reliable supplementary materials. The following two chapters give a brief overview of the particular geographical and environmental features associated with the Turpan Depression. This is helpful in understanding the type of agriculture that is practiced in this basin, and the particular measures which the people of Turpan must employ to combat the sand and wind in order to protect the farmlands. In addition, an understanding of these distinctive agricultural practices can provide significant clues in making interpretative decisions during the mapping of the oasis agriculture. This understanding then sets the basis for the definition of oasis agriculture used in this study. The final chapters outline and summarize the results and problems associated with mapping the oasis agriculture of the Turpan Depression from Landsat imagery and assess the land reclamation effort in this area.

CHAPTER II

THE STUDY AREA

To provide a better understanding of the Turpan Depression, this chapter includes a basic discussion of some of its geographical and environmental features.

A. Physical Setting

The Turpan Depression, China's deepest, has long been characterized as the land of fire and wind. It was a key point on the northern route of the ancient silk road and today it is made up of Turpan, Shanshan, and Toksun counties (Figure 8) covering approximately 50,000 square kilometers. The depression stretches from west to east and drops at its lowest point to 154 meters below sea level and presents a varied natural panorama of desert, oasis, gorges and sand dunes. The chief physical features are illustrated in Figure 9. Four main divisions of the depression are: (1) mountains (both north and south), (2) piedmont gravels, (3) lacustrine, habitable plain, and (4) the central lake or salt playa.

Crests of the peripheral ring of mountains form the boundaries of the Turpan drainage area. On the north and west, the Bogdo Ula and other ranges of the eastern part of the Tian Shan system rise to a height of from 12,000 to 14,000 feet above sea level. Bogdo Ula range is basically snowcapped the year around. The north range provides a protective shield limiting the penetration of cold air currents during the winter months. One of the isolated peaks in the basin is called Huo-yen mountain, with a height of 450 meters. It has a length of 90

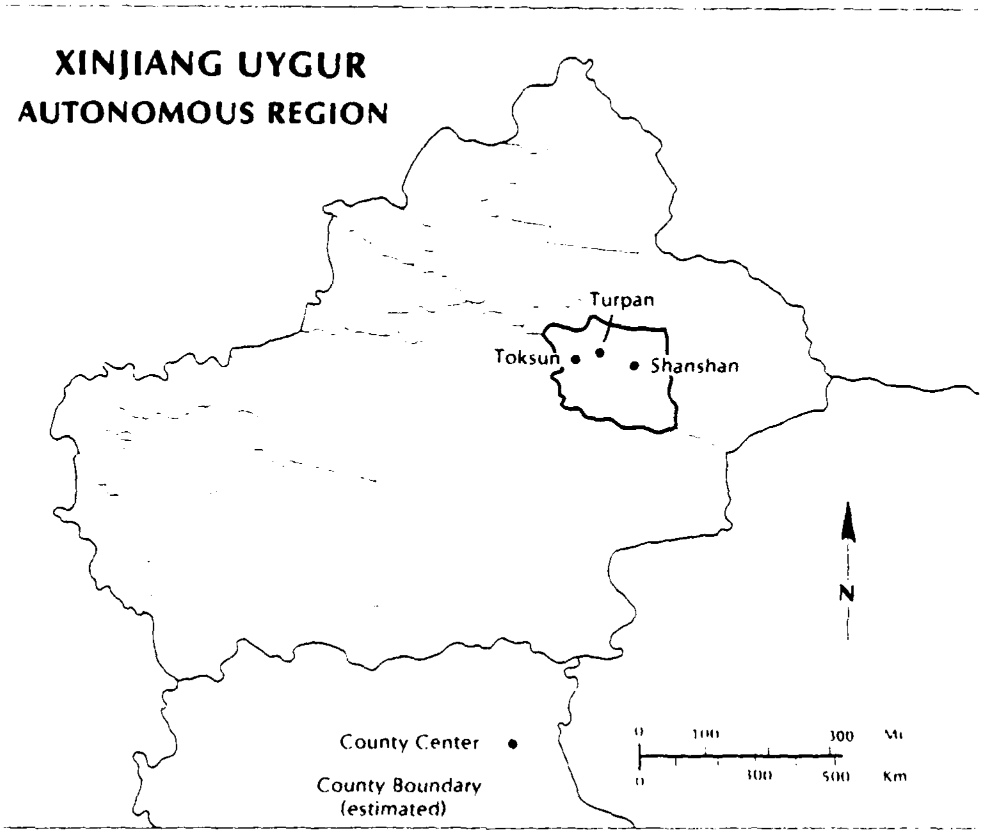


Figure 8. Administrative Divisions – Location of Toksun, Turpan and Shanshan Counties (Hsien), all under direct province-level administration. Source: The Times Atlas of China.

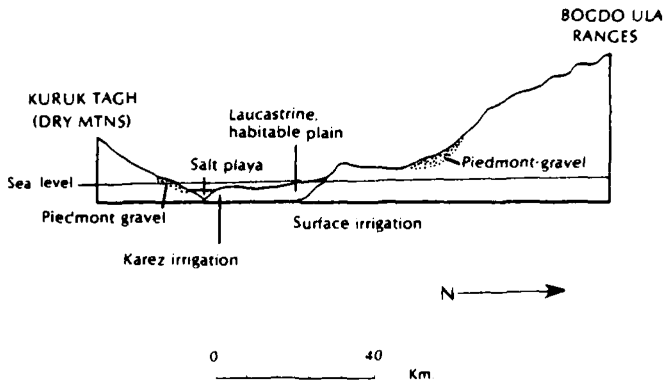


Figure 9. Cross section through the Turpan Depression, from North to South. Source: China A Geographical Survey and The Atlas of China.

kilometers and is situated north of the habitable plain. The mountains are formed mostly of Cretaceous and Tertiary rocks of red sandstone. The color of the sandstone is bright red and in the sunshine it appears as if it were on fire, hence, its name, "Flaming Mountain" (Han Hsien-kang, 1961, p. 53). In contrast to the lofty mountains on the north and west sides of Turpan, those to the south are low, well-rounded mountains between 600 and 1,500 meters in height. These mountains are very dry and well deserve the name of Kuruk Tagh or Dry Mountains.

Areas of deposition comprise the last three divisions of the Turpan Depression. In the valley to the north of the Fire Mountains is a zone of thick piedmont gravel. Ground water in this area drains by way of canyons through the Fire Mountains into the lacustrine plain below. The settlements are located on the plain in places where the water can easily be procured for the irrigation of agriculture. There is also a belt of piedmont gravel lining the southern border of the Dry Mountains.

Toward the center of the depression, the plain becomes more saline, and a few ruins remain of ancient villages. These villages became inhabitable probably because of the lack of an ample supply of water. Aydingkok is located at the lowest point of the depression. It is a salt lake, long and narrow with an approximate area of 35 square kilometers with a level that changes with the seasons (Han Hsien-kang, 1961, p. 52).

B. Turn-of-the-Century Travelers

For a long time, the principal source of cartographic information about the mountain ranges and the vast deserts of Central Asia was the map of the southern border regions of Asiatic Russia at the scale of

1:1,680,000, issued by the war-topographical division of the Russian General Staff at the end of the last century. This map contained numerous determinations of latitude and several accurate astronomic determinations of absolute longitude.

During the latter part of the nineteenth century and early part of the twentieth century, several European scholars explored the remote western frontier of China, leaving succinct accounts. The most widely known expedition was carried out by Sir Aurel Stein in the years 1900-1901, 1906-1908, and 1913-1916, under the sponsorship of the Government of India. His primary area of concentration in western China was the network of desert routes and oases from Khotan to Lop Nor. He collected and cartographically recorded a wealth of topographical information about the Central Asiatic basins and their mountainous border regions. Figure 10 is an example of the maps resulting from his explorations in the Turpan Depression. It shows the location of numerous water channels (karez), especially around the Turfan (Turpan) area. The availability of water in these areas in the early years of the 1900s can be related to the present-day oasis agricultural patterns (Figures 13-21).

Four German "Turpan" expeditions (so-called from the goal of the first party) worked along the northern route from Maralbashi to Turpan in the years 1902-1903, 1904-1905, 1905-1907 and 1913-1914. These expeditions were similar to Sir Aurel Stein's, Albert Grünwedel's and Albert von Le Coq's in the sense that a great part of their mission was archaeological in nature (Lattimore, 1950, pp. 223-224).

A new epoch in the exploration of Central Asia was inaugurated when, in 1926-1927, Dr. Sven Hedin organized a Sino-Swedish Scientific Mission

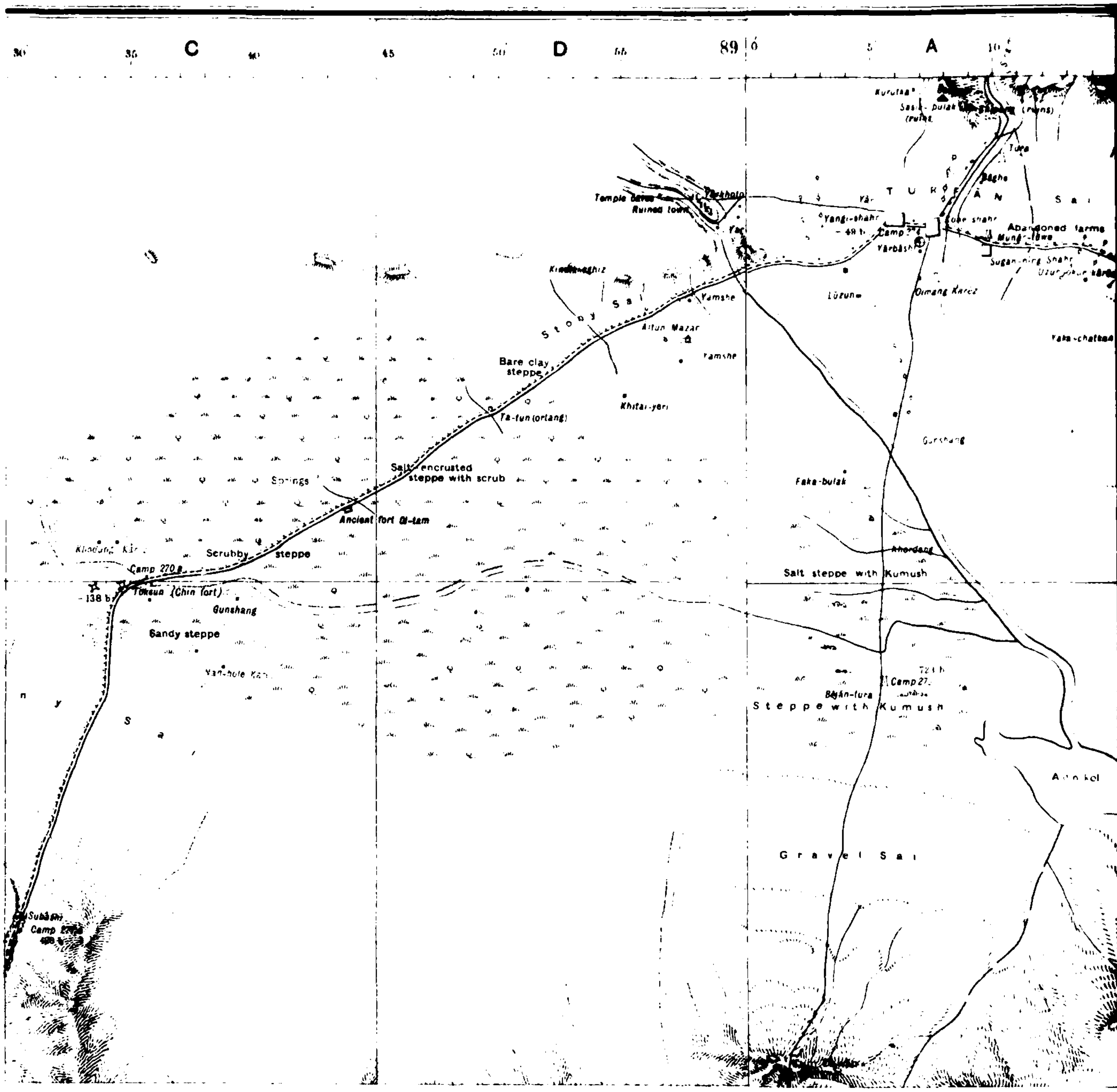
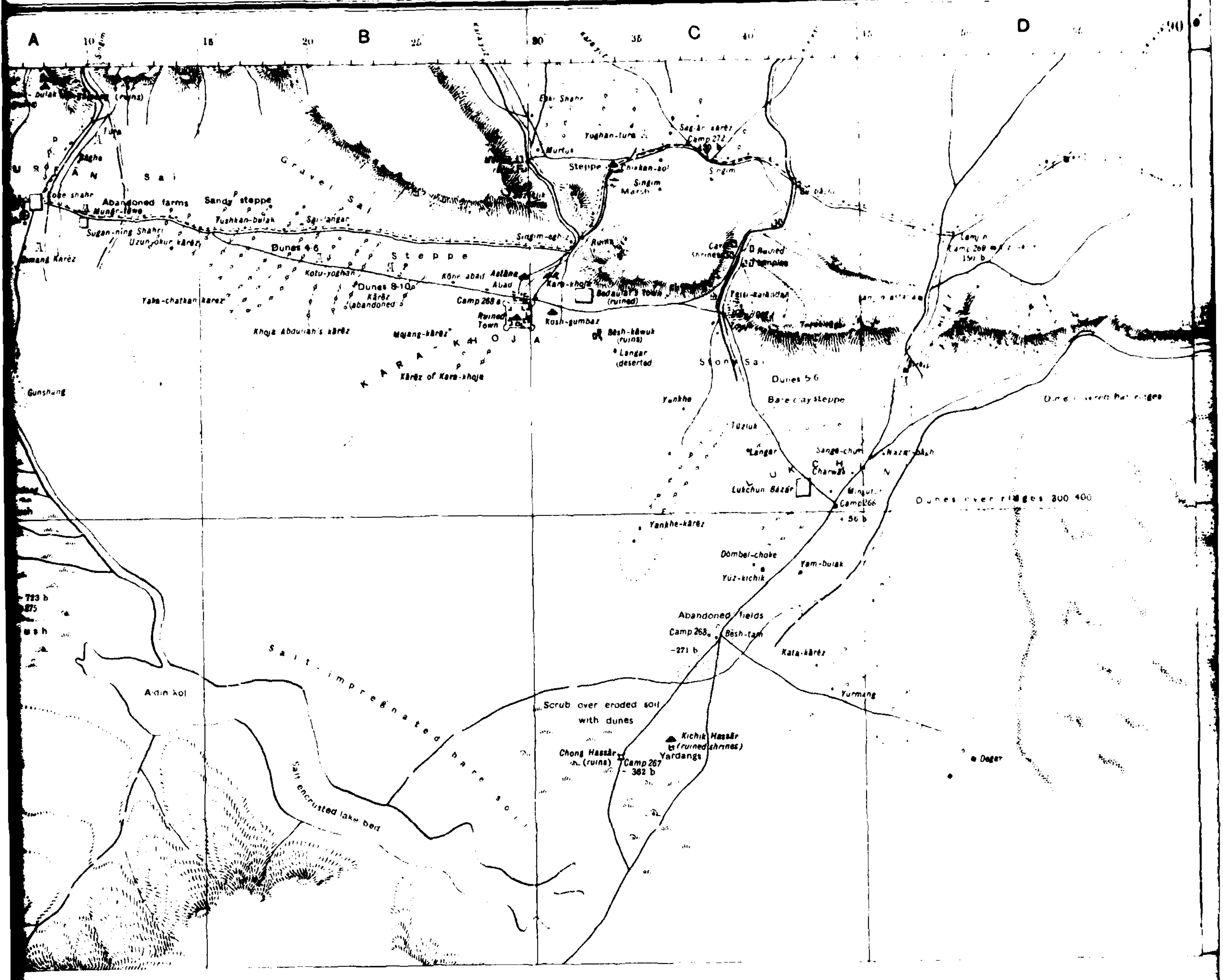


Figure 10. Map of early explorations in the Turpan Depression, by Dr. M. A



Depression, by Dr. M. A. Stein.

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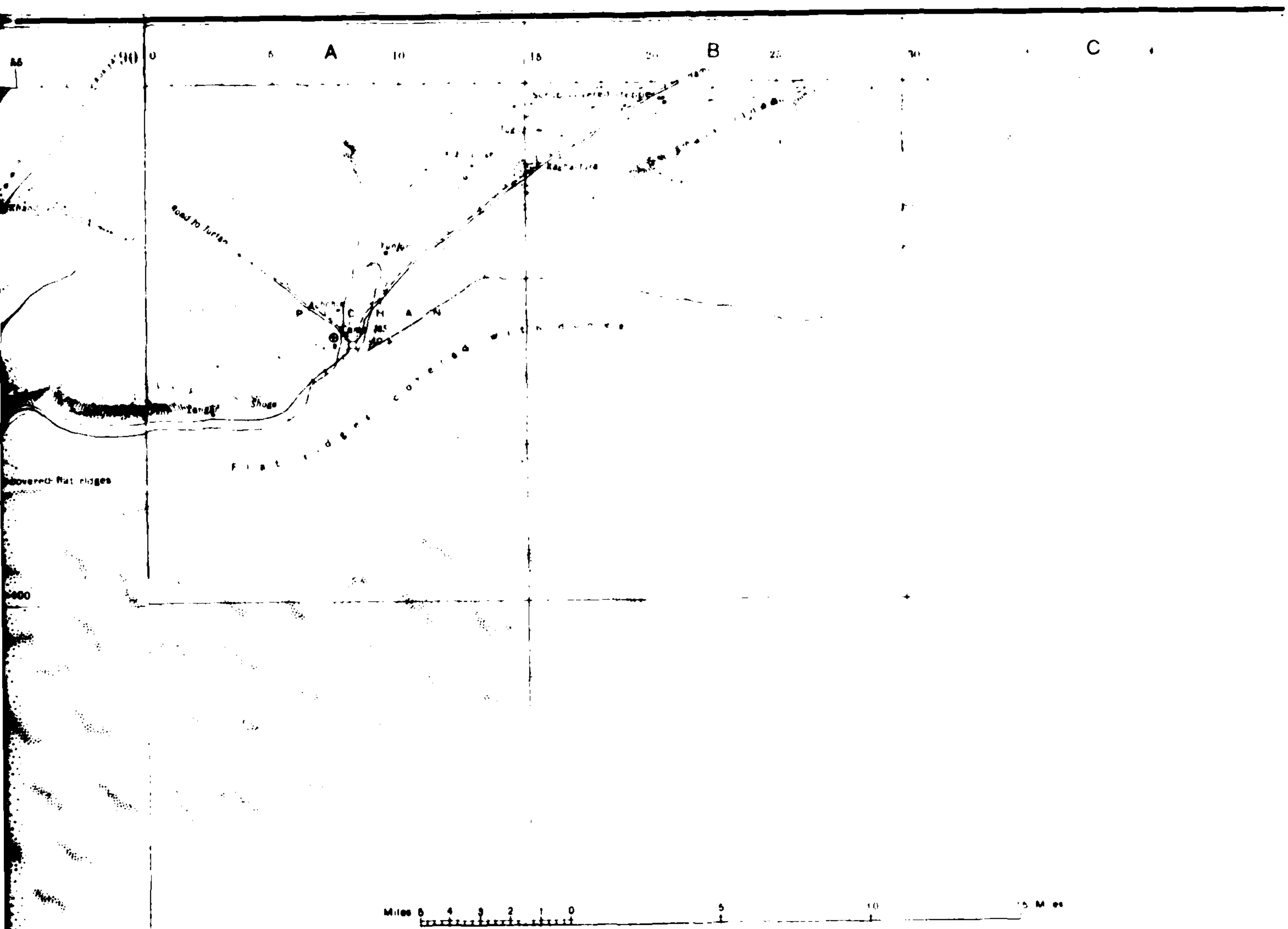

Mosaic has been compiled from Map Sheets #54 (TOKSUN), #59 (TURFAN) and #63 (PICHAN) of the series of maps of "Portions of Chinese Turkistan and Kansu To Illustrate the Explorations of Dr. M. A. Stein, etal., by the Survey of India, 1906-1908, published in 1913.

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to the north-western provinces of China in close cooperation with Chinese scientists and Chinese scientific institutions. During the field-work of the expedition in the years 1927-1933, large parts of Central Asia were covered with topographical and geological reconnaissance surveys. Dr. Hedin proposed to Justus Perthes' Geographical Institute in Gotha the construction and publication of a general map of Central Asia in 18 sheets to the scale of 1:1,000,000 according to the rules outlined by the Commission of the IMW of the 10th international Geographical Congress in Rome in 1913. Work begain in 1939 at Gotha under the direction of Professor H. Haack in close collaboration with the topographers of the expedition and in 1940-1945 three sheets were completed and printed, to include K-45 Turpan. Unfortunately, further work on the project was interrupted by the collapse of Germany in 1945 (Ambolt, 1968, p. 10).

Another early twentieth century traveler was Ellsworth Huntington. His quest for a definitive revelation of climatic pulsations took him through Asia, Europe, the United States, Central and South America, and Africa. He wrote descriptive accounts of the physical features of the great central basin of Asia and spent much time on the subject of post-glacial climatic change. During February 1906, his travels took him to the Turpan depression where he studied the area from a geographical point of view and later devoted a chapter to the Turpan depression in his book Pulse of Asia.

Owen Lattimore, the last of the travelers that will be mentioned, traveled in the frontier region during the 1920s and 1930s. He returned to the frontier territory again in 1972 and has written about the changes since the cultural revolution. He gives a short account of the Turpan depression in his article, "Return to China's Northern Frontier," where he states,

> The methods of cultivation remain much the same. The improvements include lining the banks of the canals with stone, and using the fall of water to generate electricity on a scale large enough to light every house. The major improvement, however, from the point of view of the people, has been the social revolution. Relieved of the tribute paid to landlords, and sharing in the profits of their communes, they have immeasurably raised their standard of living and well-being. To visit a few peasant households today and compare them with what one remembers from 45 years ago is proof enough. (Lattimore, 1973, p. 239)

C. Climate

The Turpan depression is the hottest spot in summer in the entire country. It is noted for a climate of great extremes of temperature. Owing to the dryness on the surface of the earth, temperatures rise rapidly in the spring. A frost-free growing season begins in the first ten days of March and ends in late October, lasting seven to eight months. Mean temperatures rise in general from March to April up to 10°C., therefore, spring comes by the end of March and summer generally begins in May. Summer lasts for up to five months with monthly mean temperatures exceeding 31°C. in the three months of June, July and August. The period with average temperatures above [illegible]°C. lasts from eight to nine months. Winter is cold and lasts five months, beginning at the end of October and ending in early March. Temperatures remain below 0°C. on the average for more than three months from late November to late February (Chu Ping-hai, 1962, p. 341). There are minor falls of snow on 4-8 days between mid-November and February each year (Arakawa, 1969, pp. [illegible]-29).

Thermal conditions in the depression are similar to those in North China, but the amount of precipitation is considerably less, only 16-30 millimeters annually. Since the basin is protected by lofty mountains in the north, moist air currents cannot penetrate readily. Moreover, the amount of cloud cover is scanty and the low humidity makes the sun strong. Monthly potential evapotranspiration far exceeds monthly precipitation (Figure 11), which is the basic cause of desert formations. The relative humidity in this region remains below 16 percent for most of the year (U.S. Joint Publications Research Service, 1958, p. 60). In the depression, all features of middle Asia's continental climate are highly pronounced.

Winds in the summer are more varied than at other times of the year. There are slightly more easterly and northwesterly winds than in winter, when the northerly winds are more common. Windstorms arriving from north Xinjiang are forced, by the topography, into velocities of tremendous speeds, and may last for three or four days especially during the spring months. Turpan has thirteen sandstorm days annually (Arakawa, 1969, p. 43).

These climatic conditions provide strict limits on the type of agriculture practiced, and make this region particularly sensitive to careful use of the water supply.

D. Water Resources

Turpan is poor in water, and particularly in surface water. Streams are small and short. In their long struggle with drought, the working people of Uygur, Han and Hui nationalities have continued to repair and expand the *karez* water system (Figure 12), a series of wells connected by

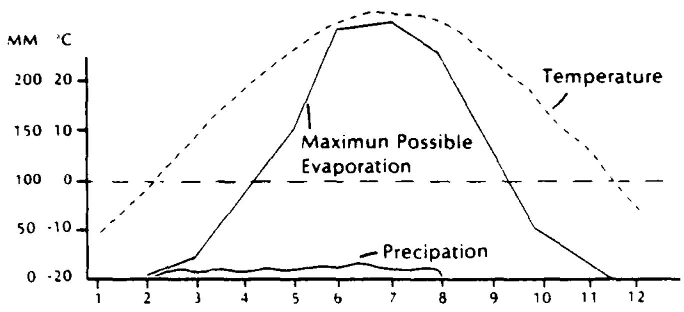

Figure 11 Turpan Depression – Evaporation vs. Precipitation. Source: Climate of China, p. 342.

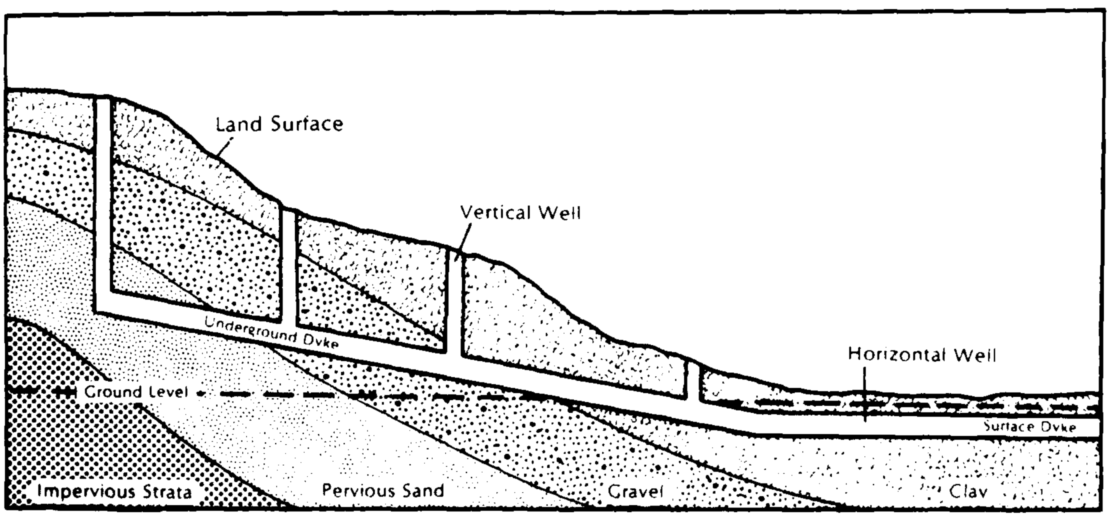

Figure 12. Karez Irrigation by means of underground water channels. Source: Atlas of China.

underground channels leading water over considerable distances from an underground water source to above-ground irrigation channels.

Starting at the foot of the Tian Shan Mountains a line of vertical shafts are sunk, and at their bottoms are interconnecting horizontal shafts leading into the center of the depression. The distance between shafts is from 80-100 meters in the upper reaches and from 10-20 meters in the lower reaches. In the foothills the shafts are as deep as 100 meters, decreasing to about 10 meters near the outlet. The heads of the shafts are covered with stones and branches to prevent evaporation and to keep the channels clear. An outlet leads to an open ditch and water is then directed to the fields. "By 1965 there were 1,300 karezes in the basin. The karezes in the basin irrigate nearly 24,000 hectares of crop land and contribute 1.6 billion cubic meters of water annually, accounting for 80 percent of the total water supply in the basin" (Chang, 1978, p. 10).

Table II gives an incomplete account of the water resource activities in the depression from 1973-1979 taken from the Summary of World Broadcasts. Even though this information may or may not be accurate in terms of figures, it does show that the people of the depression are avidly working on water projects, thereby making it possible for expanding the land under irrigation.

E. Major Crops

One of the famous crops of Turpan is long-staple cotton and its history is interesting. It has been grown for about a century and during the American Civil War, the Russian textile industry suffered great

TABLE II

WATER RESOURCE ACTIVITIES IN THE TURPAN DEPRESSION

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1. NCNA (New China News Agency) in English, 12 Oct 73, W754, 12 Dec 73, p. 5.
   In central Tulufan a commune of people of Uighur nationality built a 50 km trunk irrigation canal through the desert to lead in melted snow. It cost more than 1,000,000 yuan and 2,380,000 man days to build. Work began in 1964 and took 7 years. The canal has a flow of 12 cu m/second and has enabled the commune to enlarge its irrigated area by 2,500 hectares.

2. NCNA in English, Excerpt, 17 Feb, W765, 6 Mar 74, p. 6.
   In Turfan County . . . since the establishment of people's communes . . . the Uighur people there have worked tirelessly in building irrigation facilities and planting trees to combat drought and windstorms. They have completed 400 kanerhching--covered irrigation ditches which can reduce evaporation, 400 pump wells and 600 km of cement-or-stone-lined canals and ditches. This has enabled the county to use three times as much water for irrigation as before.

3. NCNA in English, 4 Apr 74, W771, 17 Apr 74, p. 6.
   Shanshan County increased the number of wells to 478 and pump wells to 500.

4. NCNA in Chinese, 14 Apr 74, W772, 24 Apr 74, p. 7.
   To combat drought and prevent disasters, people in Tulufan basin have repaired and sunk 147 pit wells and 23 machine-operated wells, and built more than 100 li of various types of ditches and canals.

5. NCNA in English, 26 July 74, W786, 31 July 74, p. 4.
   Three people's communes in Shanshan County have built a 1,600 Kw hydroelectric station on the Huoyen mountain by collective effort. The project was started at the end of 1969. The dam is 26 meters high and 90 meters long. A 3 km canal was dug in the mountain and 30 km of power lines were put up to bring electricity to 29 production brigades north and south of the mountain. The power station supplies enough power to irrigate 6,600 hectares of farmland.

6. NCNA in English, 6 Aug 74, W788, 14 Aug 74, p. 6.
   The earthwork done by Shanshan County over the last 6 months in building water-control projects is almost equal to the total amount for the 15 years preceding the cultural revolution. In the struggle against drought the people of the county sank 139 pump wells in addition to dredging existing wells.

TABLE II (continued) WATER RESOURCE ACTIVITIES IN THE TURPAN DEPRESSION

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7. NCNA in English, 4 Sept 76, W896, 22 Sept 76, p. 7.
   Four small hydroelectric stations were opened in the past 7 years in Shanshan County which is situated on either side of the Huoyen mountain in the Tulufan basin.

8. Urumchi, Sinkiang regional service, 27 Jul 77, W950, 12 Oct 77, p. 7.
   Shanshan County began construction of a large new reservoir on 1st July this year; when completed it will improve irrigation on 250,000 mow of land.

9. Urumqi, Xinjiang regional service, 24 May 79, W1037, 27 June 79, p. 5.
   The 77.3 m high dam in the Shanshan valley, which represents the main project of the Shitangzi is basically completed. The reservoir will have a designed capacity of 20,600,000 cubic meters and serve to adjust water supply for agricultural purposes in those areas south of the Tian Shan. The reservoir proved its use this spring when the areas south of the Tian Shan were hit by drought and the Shizigou reservoir went dry. With the 12,000,000 cu. m. of water already held there since last winter and this spring, the reservoir provided timely relief for the spring wheat in eight communes and farms in the south.

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difficulties from the shortage of American cotton. The Russian government bought American seed and introduced it in the oasis of the Tsarist conquests in Central Asia. From there it was brought to Xinjiang by private traders (Lattimore, 1973, p. 238).

Another famous crop is the Turpan raisin, dried from small, seedless white grapes. The natural conditions are particularly suitable for viticulture. High day temperatures increase the sugar content of the grapes, while cold night temperatures keep them soft and juicy. The raisins are dried in tall, mud-brick buildings. Drying in semi-darkness, with the warm desert air blowing through the perforated walls, they have a rich flavor and a high sugar content. Irrigation is essential before germination and sprouting, before flowering, during the growth period and during winter hibernation. In the months from June to August when high temperature prevails, irrigation every seven days is essential. During the period of nourishment and growth, the crop needs 20 to 30 watering sessions, each time requiring 60 to $80m^3$/mow (U.N. Conference on Desertification, 1977, p. 18).

The area also yields the famous Hami melon, but grows wheat, watermelons, apples, pears, apricots, peaches, sesame seeds, barley, and vegetables.

Table III gives a partial account of agricultural activities in the depression from 1972-1979 taken from the Summary of World Broadcasts. Even though this information may or may not be accurate in terms of figures, it does indicate a growth in agricultural development.

TABLE III

AGRICULTURAL ACTIVITIES IN THE TURPAN DEPRESSION

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1. NCNA in English, 3 Jan 72, W655, 12 Jan 72, p. 7.
   Output of Turfan grapes and honeydew melons was an all-time high.

2. NCNA in Chinese, 11 May 72, W674, 24 May, p. 6.
   In Tulufan County over 120,000 mow has been sown to wheat and the sowing of cotton on about 50,000 mow is in progress; 4,000 mow has been developed for the planting of vines.

3. NCNA in Chinese, 28 May 72, W676, 7 June 72, p. 10.
   Turfan basin has planted some 8,200 mow of grapes this year, bringing the basin's total vineyard area to more than 49,000 mow.

4. NCNA in English, 8 June 72, W677, 14 June 72, p. 4.
   In the Turfan Depression this year 546 hectares of vineyards have been planted and the total area under vines is now over 3,200 ha.

5. NCNA in English, 4 Mar 73, W715, 14 Mar 73, p. 7.
   Turfan County in 1972 had 1,200 ha. of vineyards; 9,450 tons of grapes were produced.

6. NCNA in Chinese, 19 Mar 73, W717, 28 Mar 73, p. 7.
   Rice seedlings are being grown in the Turfan basin and the sowing of spring wheat, naked barley, peas and oleaginous crops has begun in Turfan, Shanshan and Tokohsun Counties.

7. NCNA in English, 4 Apr 74, W771, 17 Apr 74, p. 6.
   In the Tulufan Depression the people of Uighur, Hui and Han nationalities have done much to change the natural conditions by removing sand dunes to create fields, opening canals and planting trees. The area is now a producer of grain, cotton, melons and fruit. Tulufan County levelled 1,400 ha. and Tokonsun County prepared 195,000 tons of fertilizer.

8. NCNA in Chinese, 14 Apr 74, W772, 24 Apr 74, p. 7.
   The people in Tulufan basin have levelled more than 20,000 mow since last winter. There are now 48,000 mow of stable and high-yield fields in the basin.

9. NCNA in Chinese, 14 Apr 74, W772, 24 Apr 74, p. 8.
   After completing spring wheat sowing, the people in the Tulufan basin are now engaged in cotton fertilization, grape-seed cultivation, and melon field sand-spreading.

TABLE III (continued) AGRICULTURAL ACTIVITIES IN THE TURPAN DEPRESSION

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10. NCNA in English, 6 Aug 74, W788, 14 Aug 74, p. 6.
Shanshan county achieved a better wheat harvest this year than in the peak year of 1973, after overcoming long dry spells. It added 200 ha. of autumn crops this year. The county produces grain, cotton, honeydew melons and grapes.

11. NCNA in Chinese, 11 Aug 74, W793, 18 Sept 74, p. 8.
Shanshan County has reaped a good harvest this year from its 110,000 mow of wheat fields. Sowing of autumn crops has been completed, with the total planted area expanded by 11,000 mow as compared with last year.

12. NCNA in Chinese, 19 Feb 75, W821, 9 Apr 75, p. 7.
In Shanshan County in 1974, despite serious drought, average grain yield was 415 catties per mow, while cotton yield reached 85 catties per mow.

13. Urumchi, Sinkiang regional service, 5 May 75, W828, 28 May 75, p. 6.
The people in Shanshan County reaped bumper harvests of grain and cotton in 1974. At present they are strengthening field management for more than 110,000 mow of land planted with wheat.

14. Urumchi, Sinkiang regional service, 2 June 75, W832, 25 June 75, p. 9.
Tulufan County has planted more than 117,000 mow of wheat and 52,000 mow of cotton. These crops are growing well in spite of recent adversities caused by strong winds.

15. Source not given, 7 July, W839, 13 Aug 75, p. 17.
Tulufan, Shanshan and Tokohsun Counties reaped a bumper harvest of wheat this year. Some 110,000 mow of wheat was basically harvested in Tulufan County by mid-June. Meanwhile, some 90,000 mow of late autumn crops have also been planted. Now efforts are being made to carry out field-tending of 50,000 mow of cotton and 20,000 mow of grapes in Tulufan.

16. Source not given, 25 July, W844, 17 Sept 75, p. 13.
Tulufan County has won a bumper harvest of summer grain this year after overcoming natural disasters. The county has completed the sowing of its 120,000 mow or so of sorghum. Its more than 50,000 mow of cotton are growing healthily and its 20,000 mow of grapes are bearing well.

17. Urumchi, Sinkiang regional service, 14 Jul 76, W891, 18 Aug 76, p. 6-7.
Tulufan County has completed harvesting all of its 120,000 mow of wheat. Total output is 10% above the 1975 summer crop in

spite of the serious drought, windstorms and pests that hit the county earlier this year.

18. NCNA in English, 30 Aug 76, W896, 22 Sept 76, p. 5.
In 1976, the total summer grain output in Shanshan County increased by 10% compared with 1975, and a good harvest of the nationally-known white seedless grapes and honeydew melons was achieved.

19. Urumchi, Sinkiang regional service, 6 Dec 76, W909, 22 Dec 76, p. 9.
In Tulufan County in 1976 total grain output surpassed that of 1975. Unit yield of grain for 2 years running has exceeded the figures set in the national programme for agricultural development, while unit yield of cotton has exceeded it for 12 years.

20. Peking home service, 29 May 78, W996, 6 Sept 78, p. 13.
In Tulufan County this year, the area of seedless grape, Hami melon, walnut and other economic crops has increased to 65,000 mow, 5,000 mow more than last year.

21. NCNA in English, 2 Nov 78, W1008, 29 Nov 78, p. 12.
Sinkiang Autonomous Region reports a good harvest of Turfan seedless white grapes. Total output this year is 40% greater than in 1977.

22. Urumchi, Sinkiang regional service, 12 Dec 78, W1017, 7 Feb 79, p. 9.
Turfan Prefecture has made progress in developing the cultivation of grapes and Hami honey dew melons. Grape and honey dew melon output in 1978 has increased by 40% and 10% respectively over 1977. It is planned that by 1985, the grapevine area in the prefecture will increase from the present 50,000 mow or more to 200,000 mow; and the honey dew melon area will be increased from the present 20,000 mow or more to 40,000 mow.

23. Urumqi, Xinjiang regional service, 28 Feb 79, W1028, 25 Apr 79, p. 5.
Turpan Prefecture had planted 43,800 mow of spring wheat, 18% of the planned area for the spring farming season; completed preparations for 50,000 mow of vineyard and 20,000 mow of newly reclaimed vineyards; and irrigated 180,000 mow of cotton fields.

In summary, this chapter has discussed the physical features of the Turpan depression, early travelers through the region, climate, water resources, and the major crops grown in the area. Oasis agriculture in this region is absolutely dependent upon the availability of water. From the early map showing the locations of the karezes, to the thematic maps (Figures 13-21) showing the present-day pattern of oasis agriculture, it can be stated that the major agricultural centers are located around the network of irrigation systems, and the major settlements of Turpan, Toksun, and Shanshan. The oasis agricultural pattern becomes more fragmented with greater distance from major settlement areas. Chapter III will discuss the three basic measures of desert control necessary for the protection of the oasis agriculture. Desert control measures of grass belts and forest networks contribute largely to the irregular pattern or shapes of the oasis agricultural areas as shown in Figures 13-21.

CHAPTER III

MEASURES OF DESERT CONTROL

A. General

The Turpan depression has been an agricultural area of varying degrees of prosperity since ancient times. After the founding of the People's Republic of China, the people followed the example of "In agriculture, learn from Tachai" movement, making achievements in combatting the wind and sand and in transforming the Gobi land into productive farmland.

To better understand the situation of how the people of the Turpan depression deal with their particular problems of wind and sand, a summary of the measures taken in combatting desertification is given below (U.N. Conference on Desertification, 1977). This type of land management will later help to explain the definition of oasis agriculture, that will be used for this study in determining cropping extent from Landsat imagery.

B. Contain-Sand-Cultivate-Grass Belts

Vast areas of land on the periphery of the oasis, with soft and loose surface structure, are extremely vulnerable to wind erosion and wind drift. Therefore, it is extremely important to increase and strengthen the plant cover of the land (Photograph 1). Contain-sand-cultivate-grass measures have developed in recent years into irrigation with water and manual cultivation of grass. Principal species for this purpose, planted along the edges of the farmland, are camel thorn

Photograph 1. Contain - sand - cultivate - grass belts.

(Alhagi pseudalhagi), mixed with "plump maiden" (Karelinia caspica) and "deer horn grass" (Scorzonera divaricata turcz). On sandly land with a higher ground water table and a higher degree of mineralization, the chief varieties are reed (Phragmites communis), tamarisk and some halophytes (Halostachys belangerina, for instance), while "mouse melon" (Capparis spinosa) dominates the scene on wind eroded land. It has been observed that (Table IV) in contain-sand-cultivate-grass belts with an 80 to 85% cover of camel thorns, the surface roughness factor increased from 0.0344 to 1.36 and wind velocity near the land surface is reduced by 50.5%.

TABLE IV

CHANGES IN SURFACE WIND VELOCITY AND SURFACE ROUGHNESS BROUGHT ABOUT BY CONTAIN-SAND-CULTIVATE-GRASS MEASURES

Land type	Land surface wind velocity		Land surface roughness	
	(m/s)	relative value %	(cm)	relative value %
Wind-eroded land outside oasis	9.9	100	0.0344	100
Areas with 85% cover of camel thorns	5.0	50.5	1.36	3953

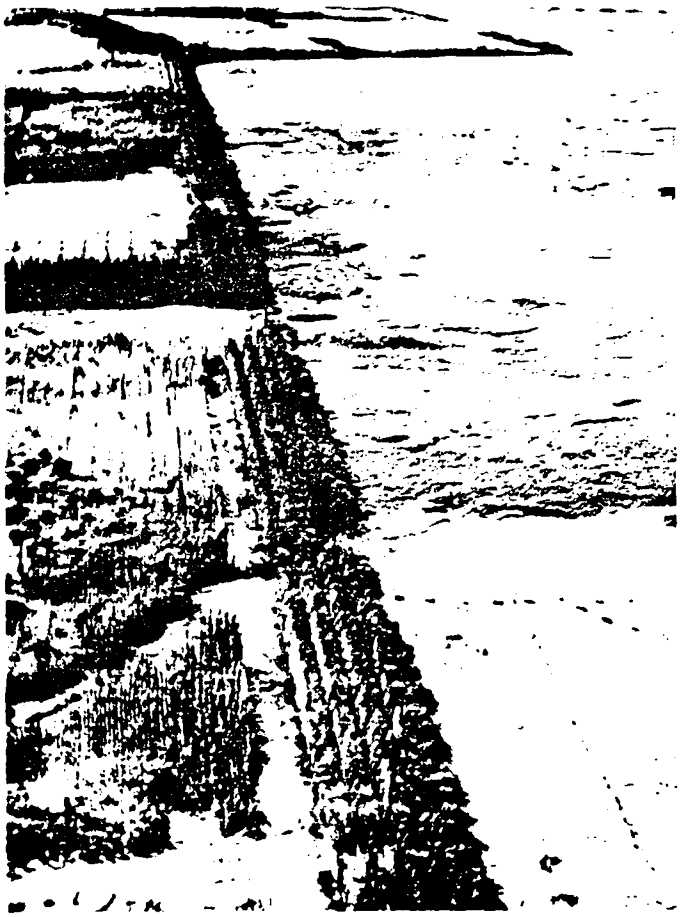
Plants within the grass belt are relatively small (mostly under one meter) and the wind shadow range is limited, but due to the width of the belt and density of the vegetation, air currents passing through the belt are progressively weakened. Therefore, an adequate width of the belt and density of vegetation are essential conditions for reducing the wind velocity and preventing the blowing off of sand. Meanwhile, the belt blocks shifting sand and protects the young forest from being buried under sand (Photograph [illegible]).

C. Stop-Wind-Block-Sand Forest Belt

The function of a stop-wind-block sand forest belt on the oasis fringe is to further weaken the wind-sand velocity, causing the deposition of smaller grains of sand that have been carried across the green belts. Two types of forest belts are used to deal with different types of wind erosion and wind drift and varying quantities of sand sources. In wind-drift areas of abundant sand source [illegible] multiple-strip forest belts are constructed, with the strips [illegible] meters apart. In wind-eroded areas of lesser sand source [illegible] are erected belts of large and tall trees of a fairly dense structure. The former belts are still at an early stage of growth and their effect on the shifting sand is not yet conspicuous; the latter, as exemplified by the 5-ditch forest belts of the Five-Star Commune have the following features: irrigation ditches parallel to multiple forest strips, trees chosen for their quick growth and long life, and tall varieties integrated with short ones. This combination of forest and ditches has the advantage of controlled use of irrigation water, preventing salinization and alkalinization, and using the water to wash away accumulated sand.

Sand dates (Elaeaghus angustifolia) are planted along the first windward side ditch for their relatively high wind-sand resisting

Photograph 3. Stop - wind - block - sand forest belts in wind - drift areas.



Photograph 4. Stop - wind - block - sand forest belts in wind - eroded areas

capacity and their salt-alkali tolerance. Moreover, during their early stages of growth, they serve as a shrubbery shield alongside the forest. Along each of the two ditches inside the forest are planted homogeneous rows of different varieties, one row of Xinjiang poplar (Populus folleana) and one row of elm (Ulmus pumila). Along each of the two ditches on the leeward side are planted one row of Xinjiang poplar and one row of mulberry (Morus alba). This arrangement increases the roughness of the forest top, thereby, increasing its capacity to diminish the wind velocity.

D. Farmland Protective Forest Network

After contain-sand-cultivate grass belts and stop-wind-block-sand forest belts have effectively weakened the force of the wind-sand attack, further weakening the remaining wind force falls upon the farmland protective forest network within the oasis, which plays a central role in the elaborate system of protection. In the experience of the Turpan people, narrow forest strips coupled with small forest networks (Photograph 5), provide the most effective means of checking wind velocity and protecting the farmland.

The selection of the appropriate species of trees and their proper arrangement are the essential conditions for the high efficiency of the narrow forest strips. White elm and Xinjiang poplar, are the backbone of the strips. On the windward side are added sand dates, which with their profuse, low-hanging foliage, have the effect of shrubbery under the trees during their early stages of growth, and when full-grown, provide the white elms with a side shield. Mulberries and apricots,

Photograph 5. Farmland protective forest network - narrow forest strips and small network plots.

varieties of economic value, are planted on the leeward side of the belt. In addition to their economic value, their extending tops add to the width of the belts. The width of the forest strips varies between four to eight rows of trees or between 6 to 12 meters. To facilitate arrangement and selective cutting, and replacement, each row is homogeneous and rows of different species run side by side.

As to the size of the plots within the forest network, the decisive factors are whether the farmland is getting proper protection and whether irrigation, mechanized tilling, seeding and harvesting can be successfully carried out.

Table V gives a few statistics of recent afforestation activities taken from the Summary of World Broadcasts.

TABLE V

AFFORESTATION ACTIVITIES

1. Urumchi, Sinkiang regional service, 30 Mar 72, W670, 26 Apr 72, p. 11.
   In Tulufan County there are some 40,000 mow of shelter belts and industrial plantations which occupy over 10% of the total area under cultivation.

2. NCNA in Chinese, 11 May 72, W674, 24 May 72, p. 6.
   In Tulufan County over 1,000,000 trees have been planted this spring.

3. NCNA in English, 17 Apr 73, W721, 25 Apr 73, p. 7.
   Shelter belts are being established in the Tarim and the Tulufan basins to protect farmland from sandstorms. This year 4,000 hectares has been afforested, 2,600 hectares of saplings cultivated and 25,000,000 trees planted along roads and rivers and around houses.

4. Source not given, 22 Mar 76, W877, 12 May 76, p. 7.
   Tulufan County has planted 18,000 mow of windbreaks to protect crops. The county has cultured 500 mow of saplings and planted more than 500,000 trees.

In combatting the sand and wind dilemma in the Turpan Depression, three basic measures have been employed to protect the farmland, they are: (1) establish grass belts on the periphery of the agricultural land, (2) establish forest belts on the fringe of the farmland and (3) within the oasis establish narrow forest strips and small forest networks. When mapping this type of oasis agriculture from Landsat, it becomes necessary to broaden the definition of irrigated agriculture slightly to account for the forest belts that are intermixed with the agricultural lands because their separate delineation is not possible. Chapter IV will discuss the identification, definition, classification and problems associated with the mapping of oasis agriculture.

CHAPTER IV

OASIS AGRICULTURAL MAPPING FROM MULTISPECTRAL LANDSAT IMAGERY

Oasis agriculture was mapped from 1:1,000,000 scale color composite transparencies enlarged to the scale of 1:250,000 with the aid of the zoom transfer scope. Within the mapping procedure, three preliminary steps were undertaken: (1) first to determine whether or not the Turpan Depression's oasis agriculture could be identified and mapped from the Landsat imagery; (2) to formulate a basis for classification of oasis agriculture from the satellite data; and (3) to assess the general and specific cartographic problems that would be encountered when mapping the oasis agriculture from Landsat.

A. Identification of Oasis Agriculture from Landsat Imagery

As mentioned above, the first priority of the study was to establish whether or not oasis agricultural lands were identificable and mappable from the multispectral satellite imagery (Figures 8-12). In any image-interpretation process certain steps are taken and definite factors are analyzed. Initially, the most obvious visible features were noted. The typical features included: mountains, rocky piedmont gravel, sand dunes, lacustrine plain, playa, drainage patterns, and lakes, all imparting a distinctive pattern to the scene. Empirical analysis of the Landsat data showed that the oasis agricultural lands of the Turpan Depression could be detected from color composite imagery. Delineation of oasis agricultural lands from remotely sensed data depended upon several criteria that were essential to the interpretation of the imagery: (1) tone--distinguishable variations in shade, (2) color--the property of an object which is related to the wavelength of the light it reflects, color provides the interpreter with expanded contrast between tones, (3) texture--frequency of the change in tone and the arrangement of tones, the visual impression of roughness or smoothness, (4) pattern--regularity and characteristic placement of tones and textures, (5) association--the combination and arrangement of the objects under consideration in reference to other related features, (6) site--location with respect to terrain features or other objects, (7) shape, (8) shadow, (9) size, and (10) resolution--the degree of sharpness or clarity of an image.

Texture, association, and site were used to a lesser degree in the identification of oasis agriculture, although the most concentrated areas of agriculture were located around the settlements of Turpan, Toksun and Shanshan. Pattern, the repetition or spatial arrangement of interpretational targets, was another visual guide for the identification of oasis agriculture. Even though the oasis agriculture did not portray any regular pattern, what was recognized was a very chaotic and irregular arrangement of the oasis agricultural areas.

Tone and color are primary indices used to identify oasis agricultural lands from small scale Landsat multispectral imagery. For manual interpretation it is much easier to perceive difference in color than changes in gray values. It has been found that the human eye is not particularly sensitive to distinguishing between more than approximately eight shades of gray values (Robinson, 1969). Therefore, since color discrimination was considered an important variable for visually delineating oasis agriculture in the Turpan Depression, Landsat color composite transparencies were procured.

Color enhances the detectability of oasis agriculture from imagery because clarity is increased and finer details can be distinguished. Because of the infrared properties of Landsat color composite data, green vegetation appears in various shades of red, bare soil is bluish-green, and water exhibits varying shades of blue tonal signatures. Differentiation in colors, therefore, permits easier detection and delimitation of oasis agricultural lands with greater detail from color composite imagery, particularly at the soil/vegetation interface than would be possible with separate black and white band imagery.

Shape and shadow are two components of image interpretation which have least utility in distinguishing oasis agriculture from Landsat data. Oasis agriculture conforms to the physiography of the basin in particular, to accessibility of water, but it has no particular form in this depression other than being very irregular in shape. Shadows created either by terrain or clouds also can be a hindrance to oasis agriculture mapping from Landsat imagery rather than an aid to interpretation.

Size and resolution are the most important elements that influence interpretation of oasis agriculture from Landsat data. The size of oasis agriculture visible on Landsat imagery is directly associated with the scale of the imagery used. Hence, it is more difficult to identify oasis agriculture, particularly small parcels of oasis agriculture at the 1:1,000,000 than it is at the enlarged scale of 1:250,000.

The minimum area that can be delimited on Landsat data is also affected by resolution of the imagery. Resolution is an extremely complex parameter of remote sensing, but it is generally defined as the ability of an imaging system (i.e., lens, filter, detector, emulsion, exposure, and processing) to record details that are detectable and recognizable. Resolution of any remotely sensed imagery is directly proportional to: (1) brightness of the object to be resolved in contrast with the background against which it is imaged; (2) aspect ratio, or ratio of the object length to the object width; (3) the object's regularity of shape; (4) number of objects that comprise the pattern to be resolved; and (5) background uniformity against which the object(s) are imaged (Reeves, 1975, p. 880).

Detail clarity or object detectability of Landsat data though depends on acutance or edge sharpness as well as resolution (Colvocoresses, 1973). Since the Landsat MSS is not a photographic sensor, but an electro-optical system, it is the contrast in illumination or the ability to show a sharp edge between objects that influences the detectability of oasis agriculture from Landsat imagery. At 1:1,000,000 scale, the acutance of oasis agriculture on color composite imagery is excellent and edge sharpness is enhanced by the contrast in tonal signatures between oasis agriculture and surrounding barren Gobi land. The minimum oasis agricultural parcel size that can be discerned from Landsat imagery, however, is related to a combination of edge sharpness, resolution and scale of imagery. Although oasis agriculture parcels have the same contrast as larger tracts of oasis agriculture within the study area, the small scale of imagery along with the resolution properties of the MSS system limit detection of small oasis agricultural parcels from 1:1,000,000 scale Landsat data. The minimum size measurable at the enlarged 1:250,000 scale utilizing the area grid was approximately .0001 square inch or 10 acres. Interrelationship of oasis agriculture detectability and measurability with resolution and size will be explained later in this chapter.

B. Definition and Classification of Oasis Agriculture

As demonstrated by initial examination of the 1:1,000,000 scale color composite transparencies, oasis agriculture of the Turpan Depression constituted areas that could be detected from small scale Landsat imagery. In order to map oasis agriculture from the imagery, an oasis agriculture definition and classification scheme was decided upon that would best fit the needs of the study, and that was compatible with the multispectral 1:1,000,000 scale Landsat data.

A general definition of oasis agriculture, is agriculture that is totally dependent on availability of irrigation water. In the Turpan Depression, as mentioned earlier, this is the only type of agriculture that can be practiced. However, when mapping the oasis agriculture, it becomes necessary to broaden the definition slightly to account for the particular problems associated with the agriculture activities in this area.

In Chapter III, a detailed analysis of how the people developed their agricultural lands to combat the sand and wind dilemma was discussed. It was found that they employ three basic measures to protect farmlands from desertification: (1) grow grass belts on the periphery of agricultural land, (2) establish protective forest belts on the fringe of farmland, and (3) within the oasis establish narrow forest strips and small forest networks.

Based on the above three statements, plus the examination of the Landsat imagery at an enlarged scale of 1:250,000, it was decided that it would be impractical to try and delimit the forest belts from the oasis agriculture in the mapping procedure because both the forest belts and the cropland had dark red tonal signatures. Grass belts, however, were distinguishable in lighter tones of red, but most times their boundary was extremely difficult to determine, especially when the oasis agriculture parcel was very small. Along with this examination, it was apparent that to try and distinguish different crops grown in the Turpan Depression would not be possible. Based on the resolution of Landsat images and particular land management associated with the protection of croplands, these two factors then became important in a broadened definition of oasis agriculture used in this study.

For the mapping of the Turpan Depression's oasis agriculture from visually interpreted Landsat imagery in this study, the most functional classification scheme is the system prepared by Anderson et al. (1976) of the USGS. The USGS hierarchy system is a multi-level land use and land cover classification system designed to be compatible with other classification systems as well as with remote sensor data (Table VI).

This system constitutes first and second levels of generalized land use categories compatible with remote sensor data acquired from both satellites and high-altitude aircraft. It was based on the following assumptions. (1) That level I categories could be differentiated, and compatible with imagery scales of 1:1,000,000 to 1:250,000

TABLE VI

U.S. GEOLOGICAL SURVEY LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
1. Urban or Built-up Land	11. Residential
	12. Commercial and Services
	13. Industrial
	14. Transportation, Communications and Utilities
	15. Industrial and Commercial Complexes
	16. Mixed Urban or Built-up Land
	17. Other Urban or Built-up Land
2. Agricultural Land	21. Cropland and Pasture
	22. Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23. Confined Feeding Operations
	24. Other Agricultural Land
3. Rangeland	31. Herbaceous Rangeland
	32. Shrub and Brush Rangeland
	33. Mixed Rangeland
4. Forest Land	41. Deciduous Forest Land
	42. Evergreen Forest Land
	43. Mixed Forest Land
5. Water	51. Streams and Canals
	52. Lakes
	53. Reservoirs
	54. Bays and Estuaries
6. Wetland	61. Forested Wetland
	62. Nonforested Wetland
7. Barren Land	71. Dry Salt Flats
	72. Beaches
	73. Sandy Areas Other than Beaches
	74. Bare Exposed Rock
	75. Strip Mines, Quarries, and Gravel Pits
	76. Transitional Areas
	77. Mixed Barren Land

TABLE VI (continued) U.S. GEOLOGICAL SURVEY LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
8. Tundra	81. Shrub and Brush Tundra
	82. Herbaceous Tundra
	83. Bare Ground Tundra
	84. Wet Tundra
	85. Mixed Tundra
9. Perennial Snow or Ice	91. Perennial Snowfields
	92. Glaciers

with very little supplemental information, and (2) Level II categories could be used with 1:250,000 to 1:24,000 imagery interfaced with topographic maps.

Agricultural land and Forest land are classified as a Level I land use and land cover category in the USGS system. Agricultural land may be defined broadly as land used primarily for production of food and fiber. The USGS Land Use System also establishes that the chief indications of agricultural activity will be distinctive geometric field and road patterns on the landscape and traces produced by livestock or mechanized equipment (Anderson et al., 1976, p. 13). The above indications of agricultural activity do not apply in this study. There are few distinctive geometric field patterns because of the type of land management peculiar to this area. Grass and forest belts which surround the oasis agriculture contribute to very irregular and odd shapes of the fields. Since mechanized equipment is minimal to non-existent, and no livestock are raised, no distinctive patterns are created in the fields.

At Level II, agricultural lands are subdivided into cropland and pasture; orchards, groves, vineyards, nurseries, and ornamental horticultural areas; confined feeding operations; and other agricultural land. Forest lands, at Level II are subdivided into deciduous forest, evergreen forest, and mixed forest. Forest and agricultural lands as detected from 1:1,000,000 scale Landsat data in this study are best classified at Level I, since Level II categories could not be effectively discriminated from each other using visual techniques at 1:250,000 scale and extensive supplementary materials were not available for this study.

For mapping oasis agriculture in the Turpan Depression from Landsat data, the USGS system provides a functional guideline. This system is easy to use and does not attempt to extract information that is beyond the limits of the data source. At Level I, it is the optimum classification scheme that can be used with mapping oasis agriculture of the Turpan Depression.

C. Problems Encountered in Mapping Oasis Agriculture

Although the mapping procedure was uncomplicated, there were several areas on the imagery that were difficult to map. Oasis agriculture was troublesome to delineate on Turpan imagery in three general areas.

1) Oasis agriculture in areas outside of the main oasis agriculture clusters was a problem to map because of small size. Although large oasis agricultural areas exist around the major county seats of Turpan, Toksun and Shanshan, some agricultural operations exist as extremely dispersed small parcels, thereby making their delineation a problem.

2) It was also a problem to identify and delimit oasis agriculture around county seats on Landsat imagery. Since these county seats are not highly urban or built-up areas oasis agriculture tonal signatures intermix and overshadow urban signatures and the two areas become visually inseparable.

3) Although interpretation difficulties hinder Landsat mapping procedures, it does not mean that Landsat imagery is not a viable medium for mapping oasis agriculture in the Turpan Depression. These problems' impact on the mapping procedure is mitigated considerably

when the size of oasis agricultural areas involved is compared with the entire oasis agriculture area that has been mapped in the Turpan Depression. (Section E).

In addition to the areas on Landsat imagery that were difficult to map, the problem of matching a 1:1,000,000 photographic image to a 1:250,000 scale cronoflex base map of the area with the aid of the zoom transfer scope created some difficulty. All cultural features, i.e., roads, railroad and airfield were used first for matching of the image and the base map, then, rivers, lakes and especially the Huo-yen mountains with their distinctive topography were used as a second alternative for scale matching.

D. Summary of Landsat Mapping Procedure

The Landsat mapping procedure has demonstrated that oasis agricultural lands in the Turpan Depression could be identified and delimited with moderate success from 1:1,000,000 scale Landsat imagery and transferred to a base map of 1:250,000 through the use of the Bausch and Lomb Zoom Transfer Scope. The ability to discern oasis agriculture, however, depended on the interrelationship and variability of several photo-interpretation indices. Tone and color are primary factors that are used to visually detect oasis agriculture from Landsat imagery. Oasis agriculture exhibits a unique dark red tonal signature which was the key to its identification. Texture, pattern, association, and shape are ancillary parameters that aided detection of oasis agriculture from Landsat data. Minimum size of oasis agricultural areas identifiable on imagery was affected by resolution, edge sharpness, and scale of the data. The amount of detail evident on Landsat data is a dependent variable of the MSS system and the small scale at which the imagery is sensed.

Although oasis agricultural lands were features that were identifiable on the Landsat imagery, oasis agriculture had to be defined according to a classification scheme that was compatible with the scale of the data, compatible with the area's specific land management problems, and one that would be acceptable to the users of the cartographic information. The USGS Land Use and Land Cover Classification System, therefore, was used to classify and map oasis agriculture in the Turpan Depression from Landsat data. Oasis agriculture was best defined at the Level I category, since this division of the multi-level system was designed for use with 1:1,000,000 to 1:250,000 scale Landsat imagery.

Thematic oasis agricultural maps (Figures 13-21) interpreted from the five Landsat images show that oasis agricultural detail varies according to the visual characteristics of the multispectral imagery. Lack of success in illustrating a slight increase in oasis agriculture as was originally thought, according to the scant literature and Summary of World Broadcast information will be discussed in Section E. Mapping the oasis agriculture from the selected images, all involved some aspect of photo-interpretational and cartographic difficulties but these were expected from the early preview of the images.

Results of the Landsat oasis agricultural mapping procedure are acceptable. Landsat is a good medium for visually identifying and mapping oasis agriculture in the Turpan Depression. As part of land

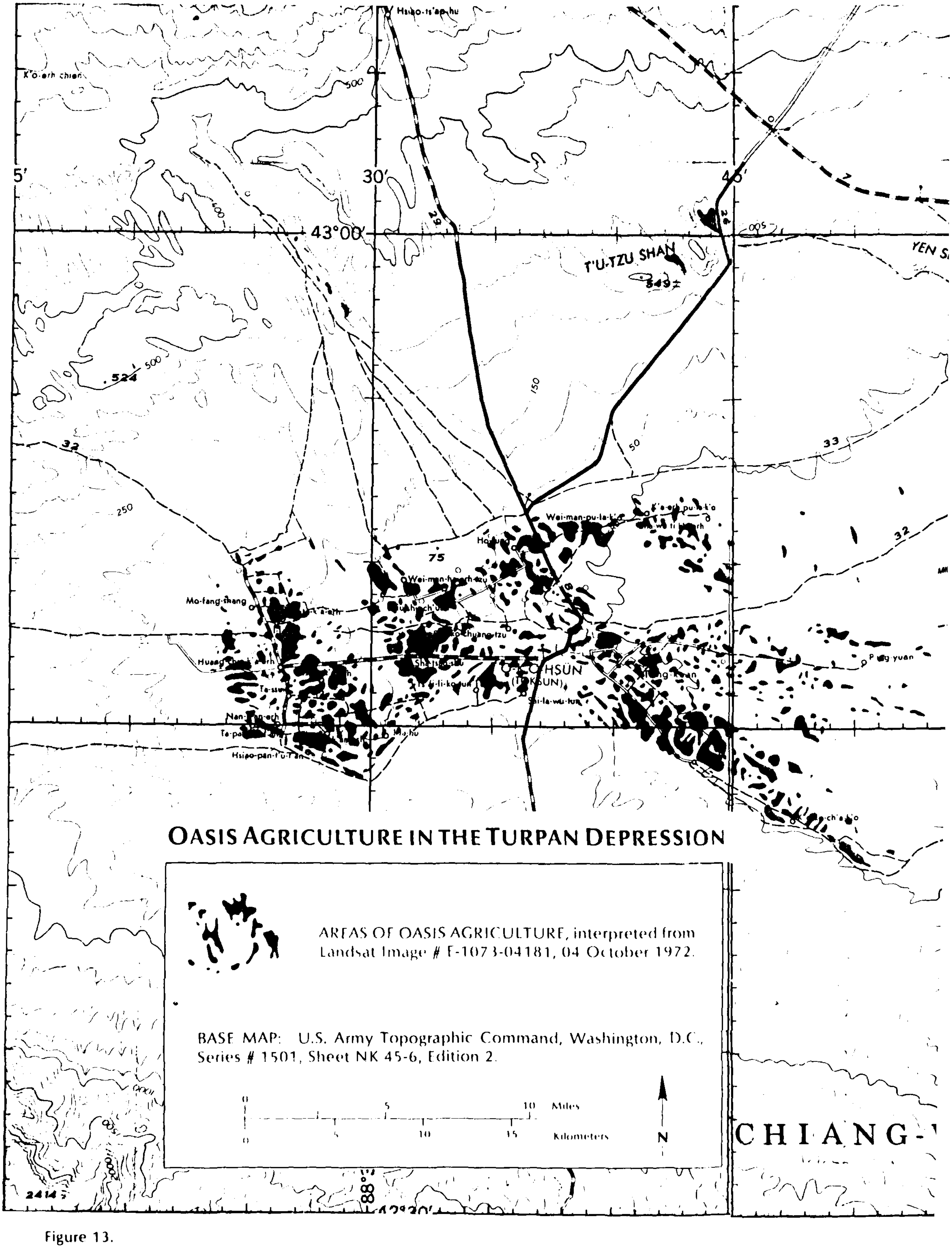
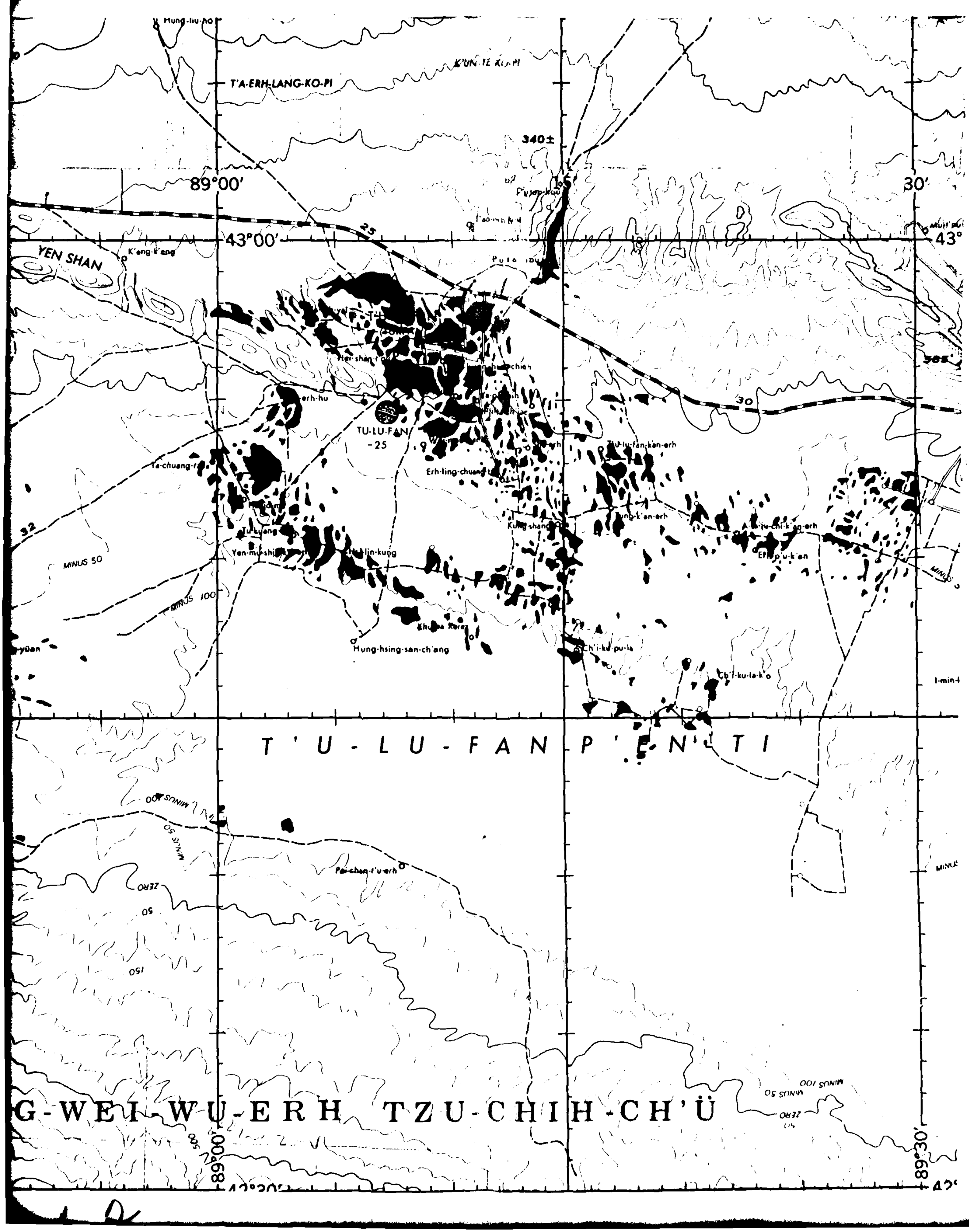

OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-1073-04181, 04 October 1972.
BASE MAP: U.S. Army Topographic Command, Washington, D.C., Series # 1501, Sheet NK 45-6, Edition 2.
0 5 10 Miles
0 5 10 15 Kilometers
N
T'U-TZU SHAN
43°00'
30'
Hsiao-ts'ao-hu
K'O-erh chien
Wei-man-pu-la-k'o
Mo-fang-shang
Wei-man-hu
Nan-hsan-erh
Hsiao-pan-t'u-t'an
Ma-hu
Ta-ssu
Sai-la-wu-tun
P'ing yuan
TO-K'O-HSUN
(TOKSUN)
YEN S
CHIANG-

Figure 13.



Hung-liu-ho
T'A-ERH-LANG-KO-PI
340±
89°00'
30'
43°00'
43°
YEN SHAN
K'eng-k'eng
25
30
TU-LU-FAN
-25
Tu-lu-fan-kan-erh
32
MINUS 50
MINUS 100
Hung-hsing-san-ch'ang
Ch'i-ku-pu-la
Ch'i-ku-la-k'o
T'U-LU-FAN P'EN-TI
Pai-chan-t'u-erh
ZERO
50
150
G-WEI-WU-ERH TZU-CHIH-CH'Ü
89°30'

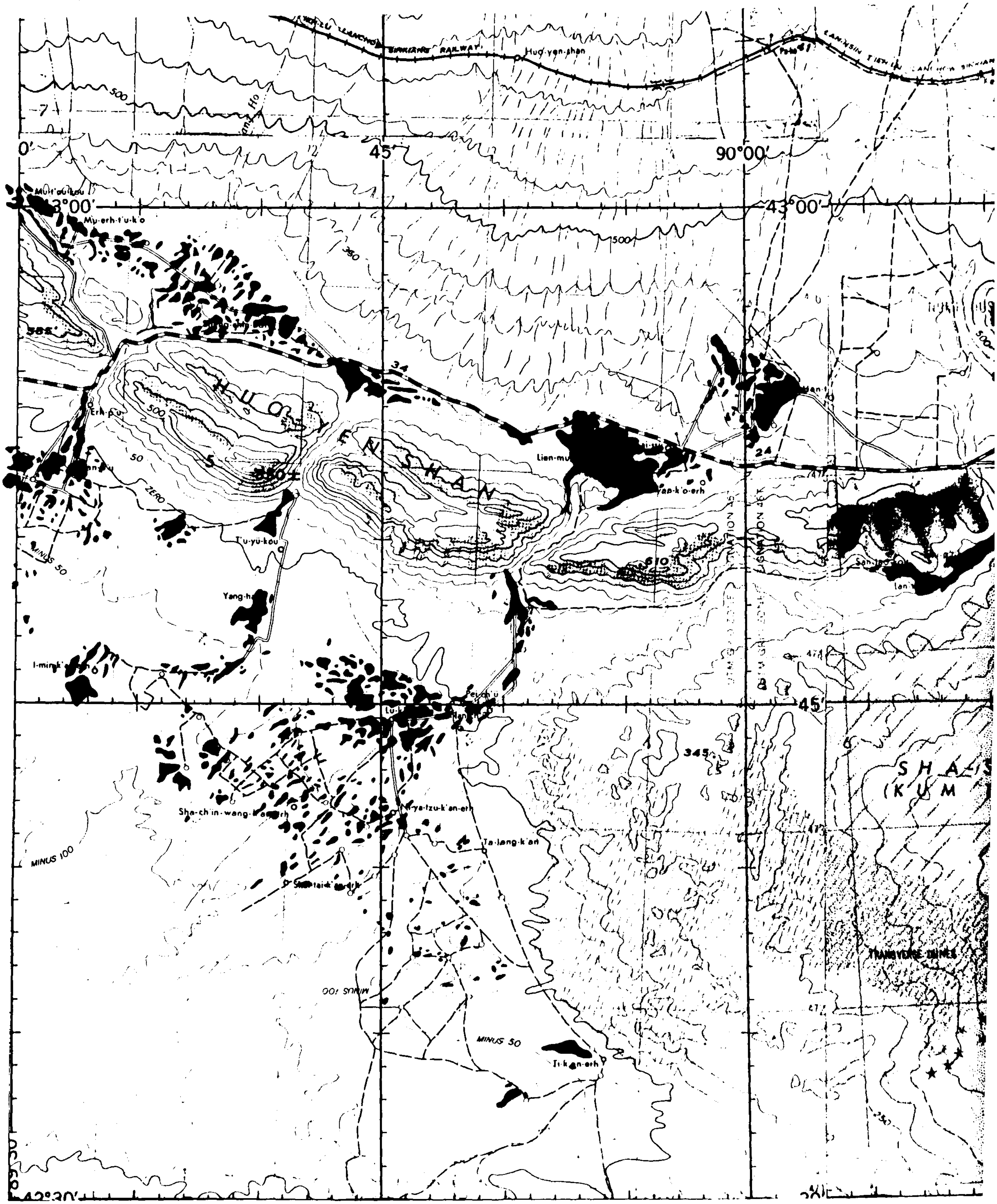
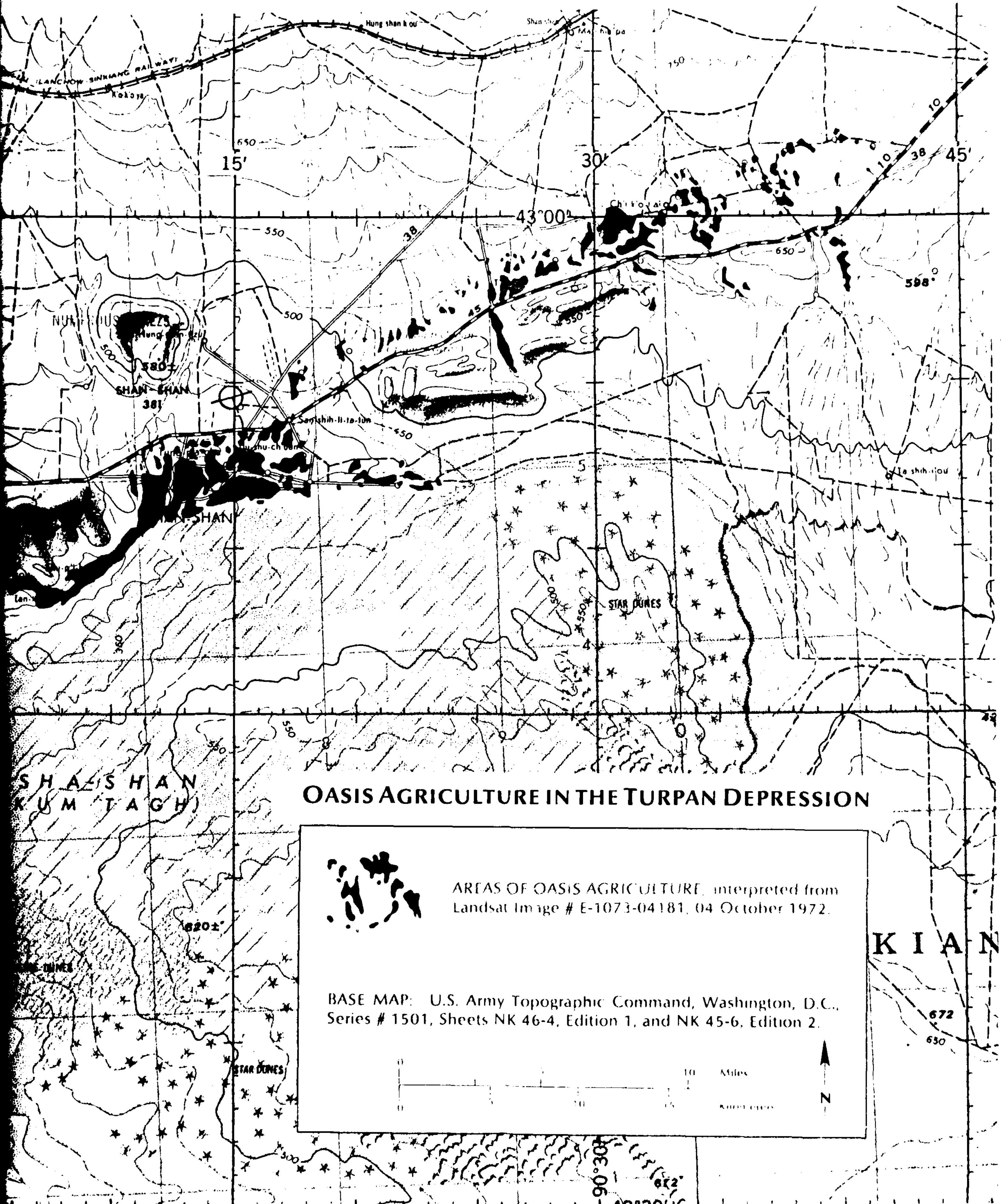

RAILWAY
Huo-yen-shan
500
90°00'
45'
43°00'
Mu-erh-t'u-k'o
HUO YEN SHAN
500
50
ZERO
MINUS 50
T'u-yü-kou
Yang-ha
Lien-mu
24
34
610
Pei-ch'ü
345
SHA-S
(KUM
Sha-ch'in-wang-k'an-erh
Ta-lang-k'an
MINUS 100
MINUS 50
Ti-k'an-erh
TRANSVERSE DUNES

Figure 14.



OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-1073-04181, 04 October 1972.
BASE MAP: U.S. Army Topographic Command, Washington, D.C., Series # 1501, Sheets NK 46-4, Edition 1, and NK 45-6, Edition 2.
0
10
Miles
N
Hung shan kou
Kokoya
15'
30'
45'
43°00'
SHAN-SHAN
381
STAR DUNES
SHA-SHAN
KUM TAGH
KIAN
598
620±
672
650
550
500
90°30'

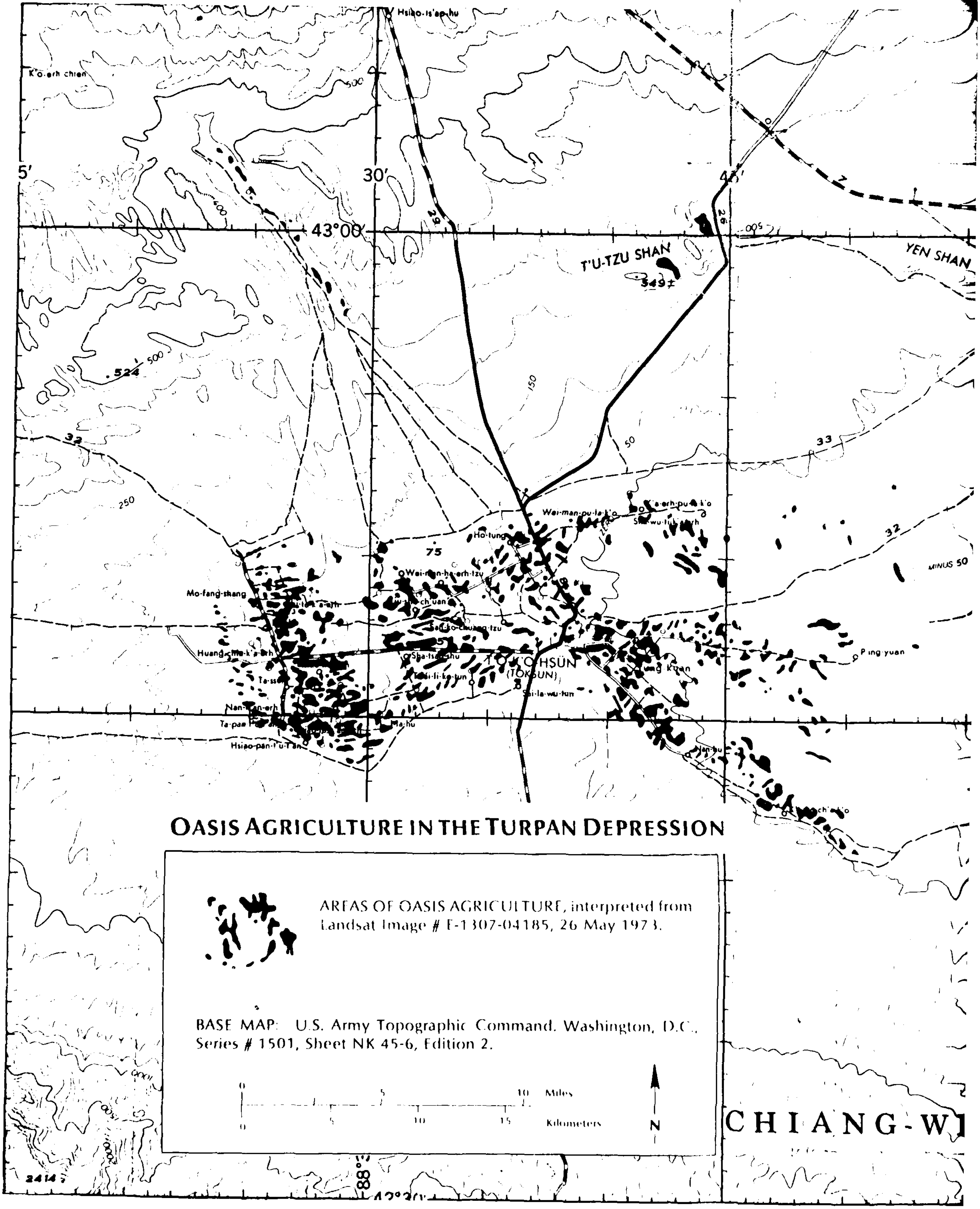
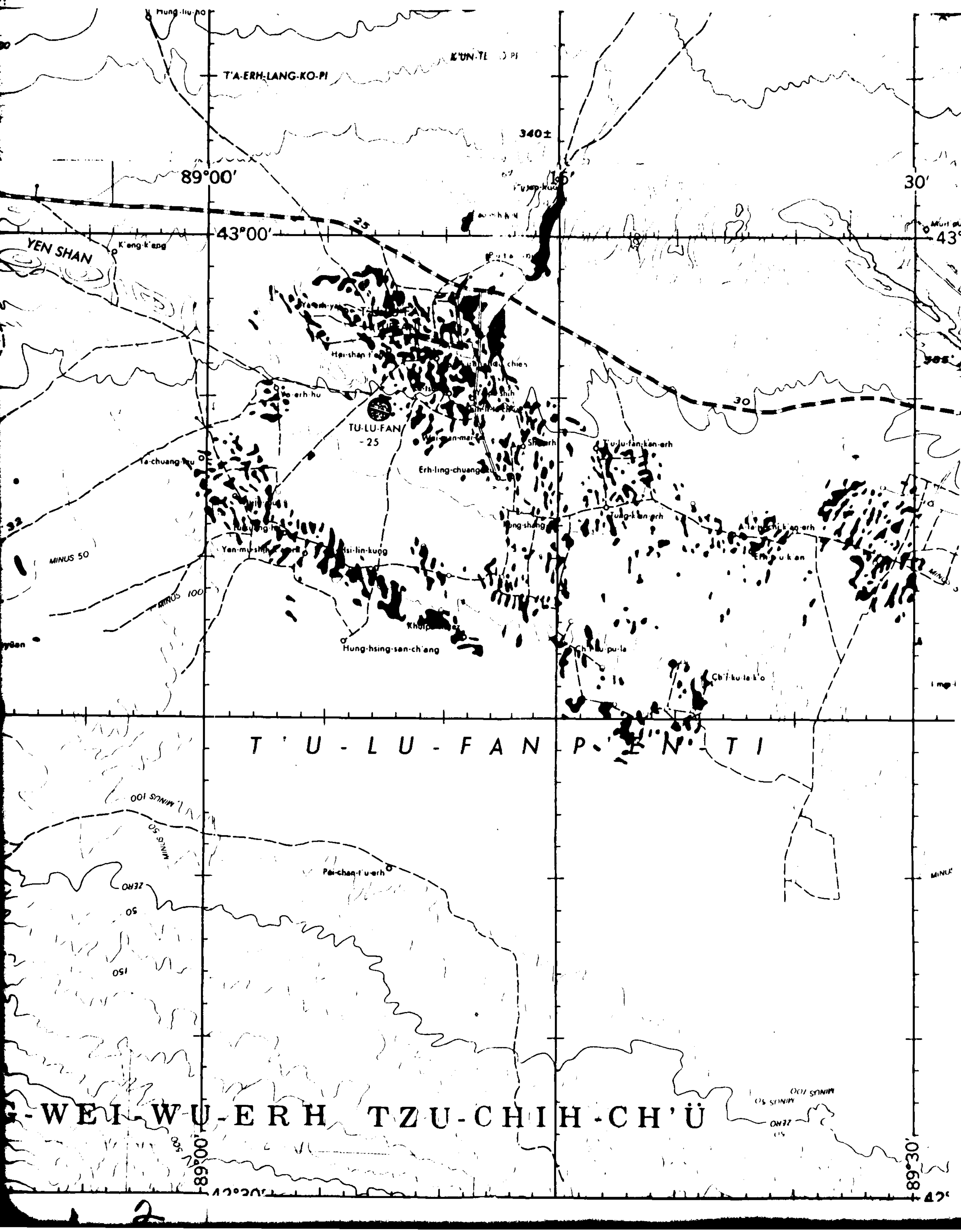
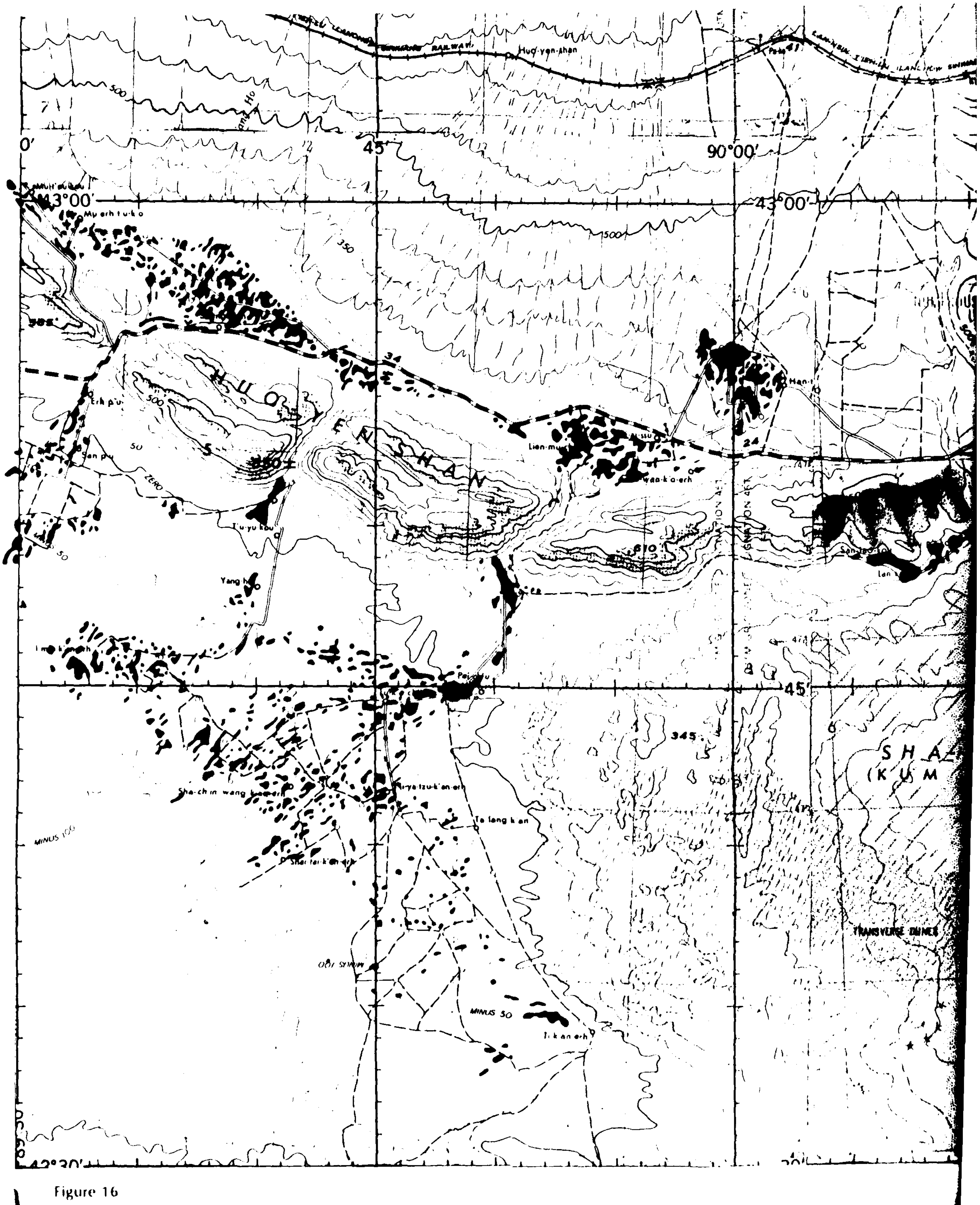

OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-1307-04185, 26 May 1973.
BASE MAP: U.S. Army Topographic Command, Washington, D.C., Series # 1501, Sheet NK 45-6, Edition 2.
0 5 10 Miles
0 5 10 15 Kilometers
N
T'U-TZU SHAN
YEN SHAN
43°00'
30'
45'
K'o-erh chien
Mo-fang-shang
Huang-chia-k'a-erh
Wei-man-pu-la-k'o
K'a-erh-pu-la-k'o
Ho-tung
Sai-ko-chuang-tzu
Sha-tsao-shu
Sai-la-wu-tun
Ma-hu
Hsiao-pan-t'u-t'an
P'ing-yuan
T'O-K'O-HSÜN
(TOKSUN)
MINUS 50
CHIANG-WI

Figure 15.

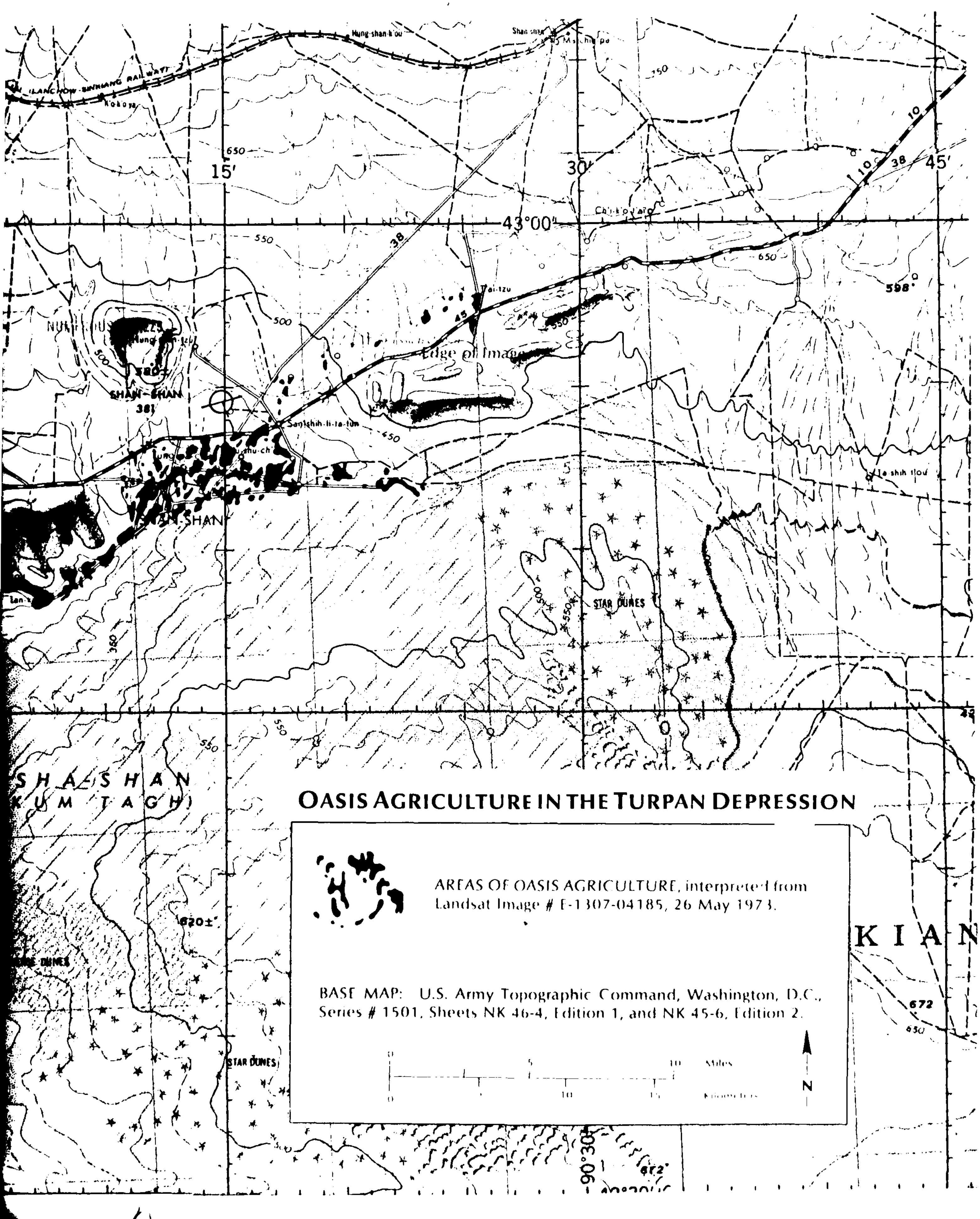


Hung-liu-ho
K'UN-T
T'A-ERH-LANG-KO-PI
340±
89°00'
30'
43°00'
43°
YEN SHAN
K'eng-k'eng
25
30
Hei-shan-
TU-LU-FAN
-25
Ta-chuang-
Erh-ling-chuang
Tu-lu-fan-k'an-erh
Hsi-lin-kung
MINUS 50
MINUS 100
Hung-hsing-san-ch'ang
Ch'i-ku-la-k'o
T'U-LU-FAN P'EN TI
Pei-chan-t'u-erh
ZERO
50
150
G-WEI-WU-ERH TZU-CHIH-CH'Ü
89°00'
89°30'
42°30'



RAILWAY
Huo-yen-shan
500
45'
90°00'
43°00'
43°00'
350
500
HUO YEN SHAN
Lien-mu
Han
Erh-p'u
Tu-yu kou
Yang-ho
Pei-chu
610
345
45'
S H A
(K U M
Sha-ch'in wang
Ta lang k'an
MINUS 100
MINUS 50
ZERO
TRANSVERSE DUNES
Ti k'an erh
42°30'

Figure 16



OASIS AGRICULTURE IN THE TURPAN DEPRESSION

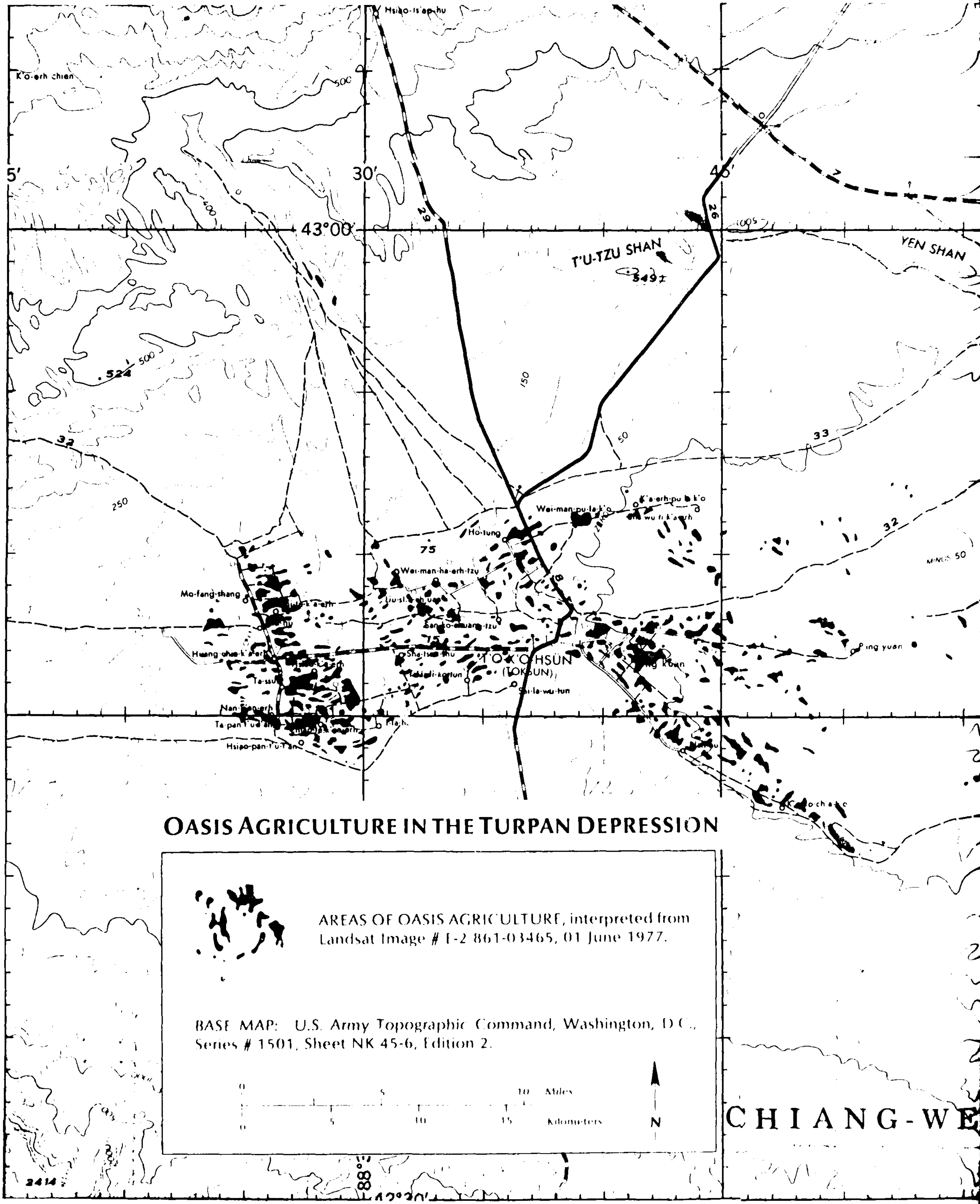
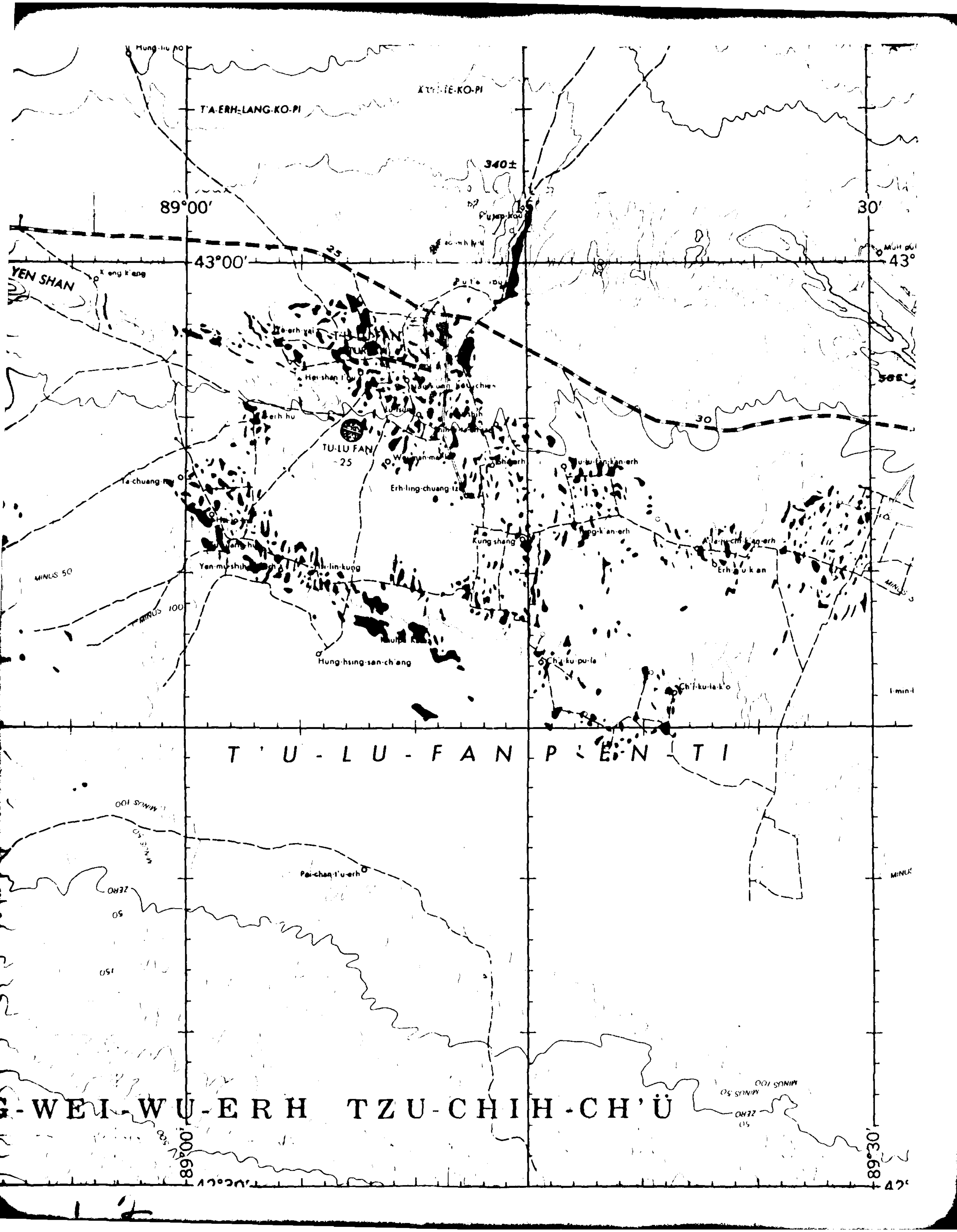
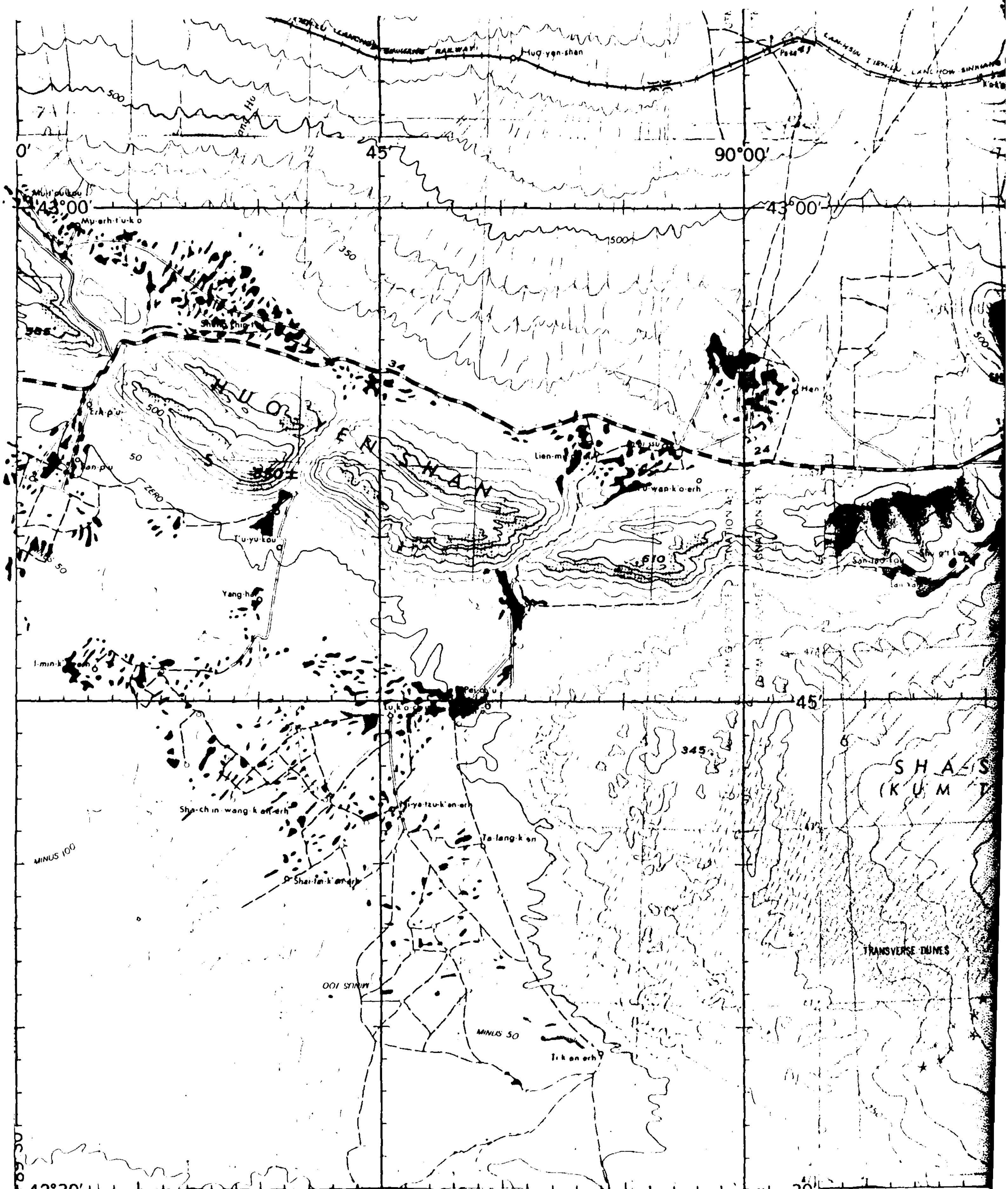

OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-2 861-03465, 01 June 1977.
BASE MAP: U.S. Army Topographic Command, Washington, D.C., Series # 1501, Sheet NK 45-6, Edition 2.
0 5 10 Miles
0 5 10 15 Kilometers
N
T'U-TZU SHAN
YEN SHAN
T'O-K'O-HSÜN
(TOKSUN)
CHIANG-WE
43°00'
30'
45'
88°
42°30'
Hsiao-ts'ao-hu
K'o-erh-chien
Ho-tung
Wei-man-pu-la-k'o
Wei-man-ha-erh-tzu
Mo-fang-shang
San-ko-chuang-tzu
Sha-tsao-hu
Sai-la-wu-tun
Ta-pan-t'u-an
Hsiao-pan-t'u-t'an
Nan-fang-erh
P'ing-yuan
2414
524
500
250
150
75
50
33
32
29
26
8
MINUS 50

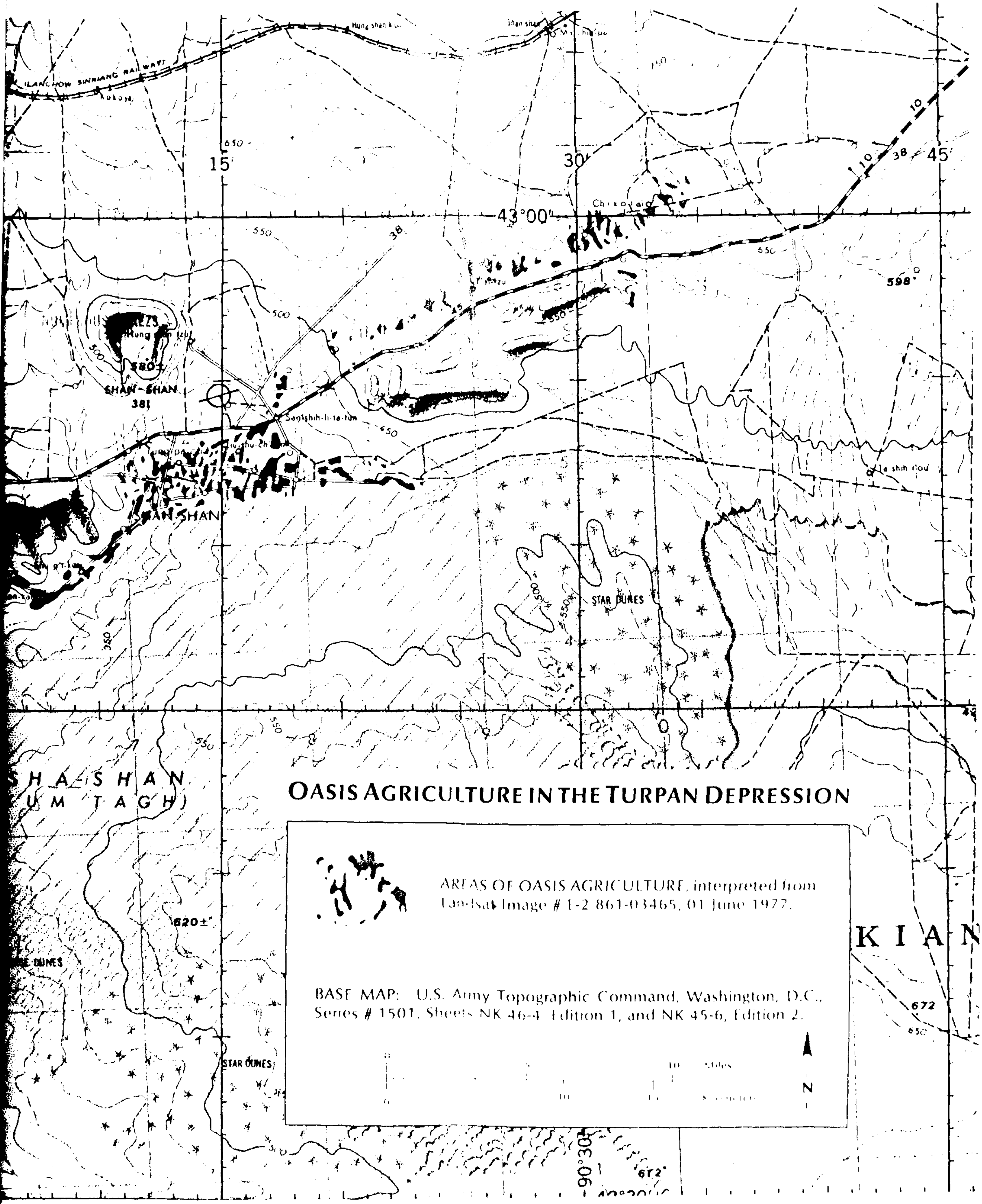
Figure 17.


T'A-ERH-LANG-KO-PI
340±
89°00'
30'
43°00'
43°
YEN SHAN
25
30
TU-LU FAN
-25
Hei-shan-t'ou
Erh-ling-chuang-tzu
Kung-shang
Yen-mu-shih
Hung-hsing-san-ch'ang
Chi-ku-pu-la
Ch'i-ku-la-k'o
Erh-pu-k'an
MINUS 50
MINUS 100
T'U-LU-FAN P'EN-TI
Pei-chan-t'u-erh
ZERO
50
150
G-WEI-WU-ERH TZU-CHIH-CH'Ü
89°00'
89°30'

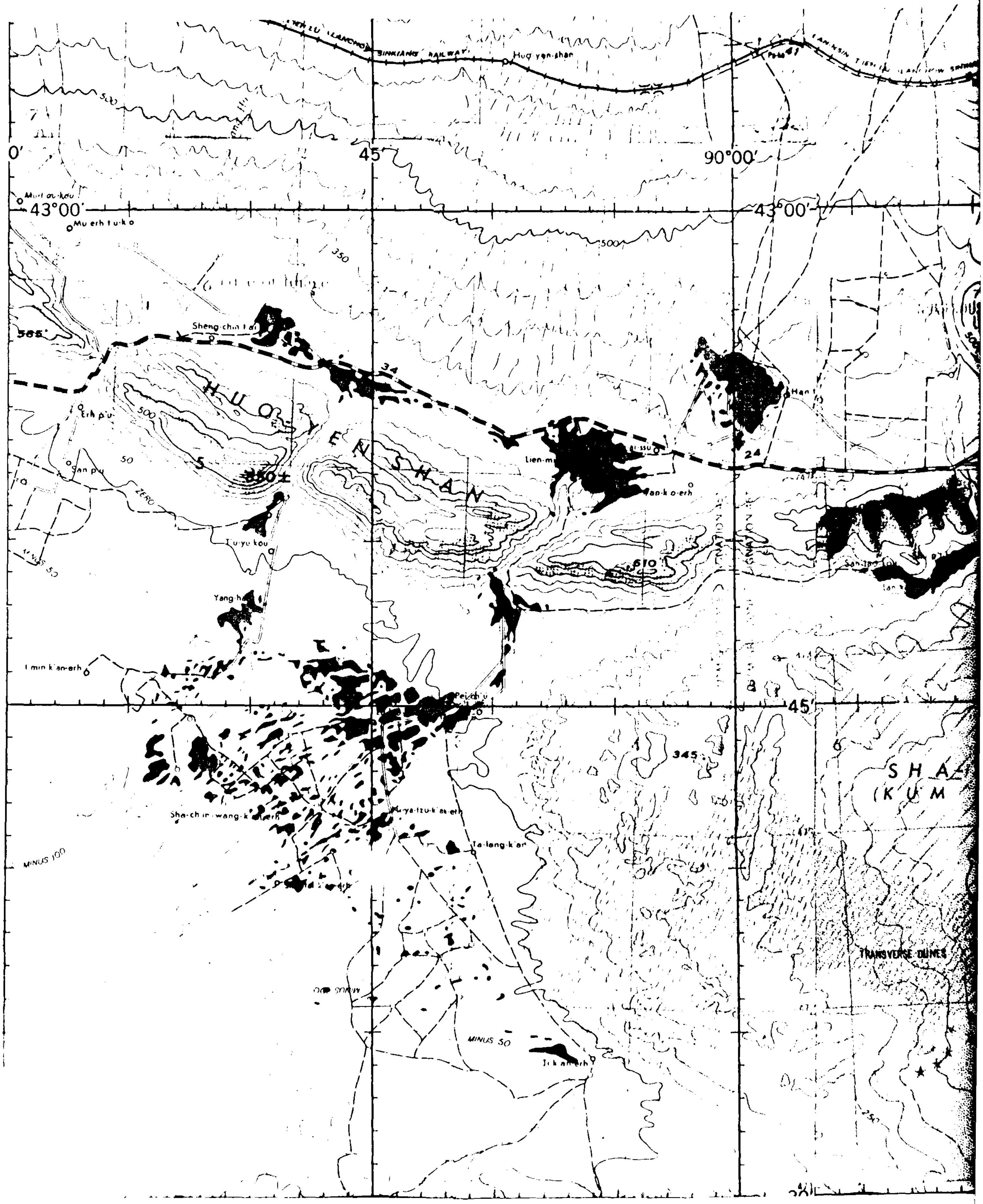


Huo-yen-shan
45′
90°00′
43°00′
HUO YEN SHAN
Mu-erh-t'u-k'o
Erh-p'u
T'u-yu-kou
Yang-hai
Lien-mu
Hen
Pei-ch'u
Lu-k'o
Sha-ch'in-wang-k'an-erh
Ta-lang-k'en
Shai-fen-k'an-erh
T'i-k'an-erh
MINUS 100
MINUS 50
ZERO
TRANSVERSE DUNES
45′
42°30′
30′

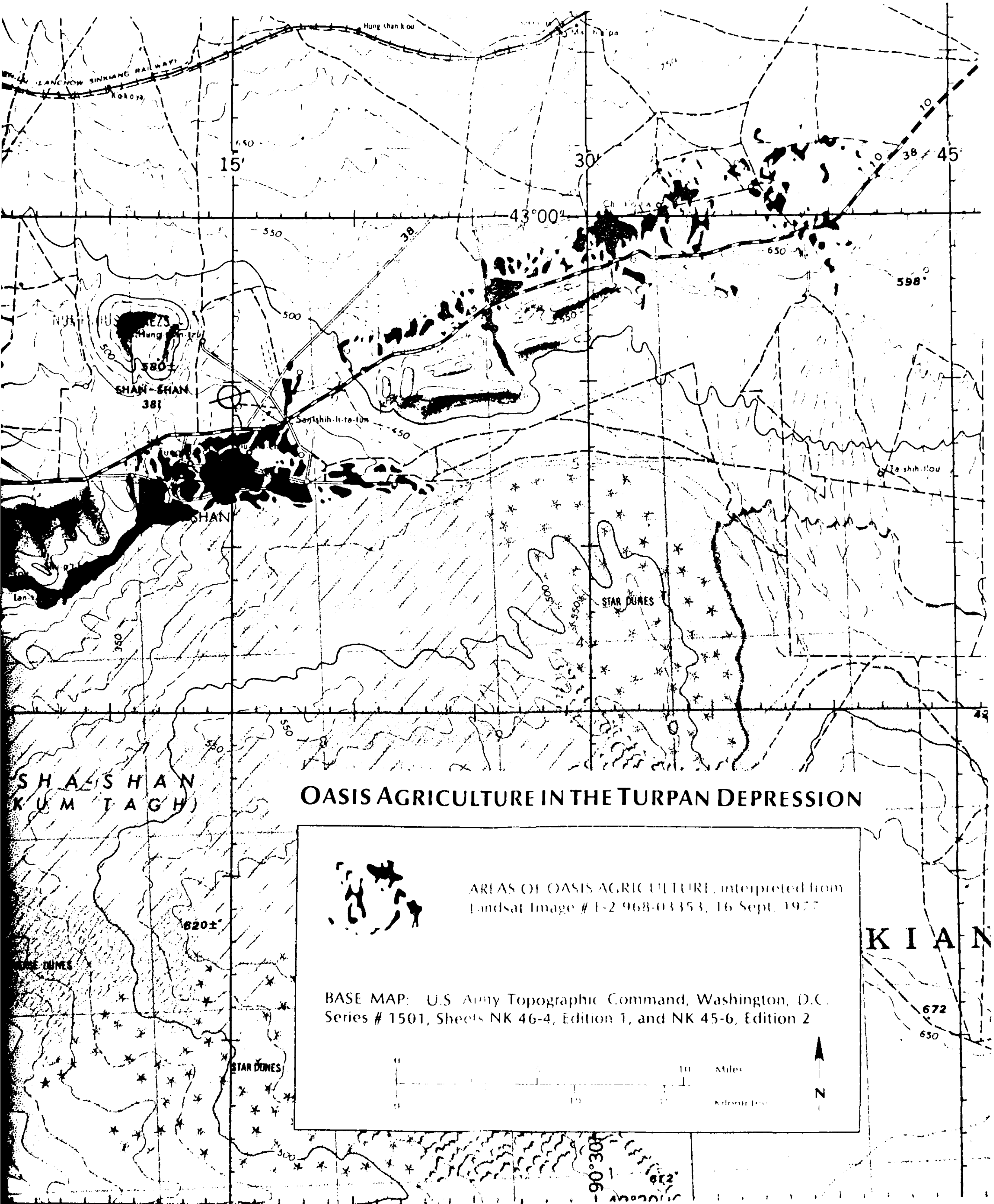
Figure 18.

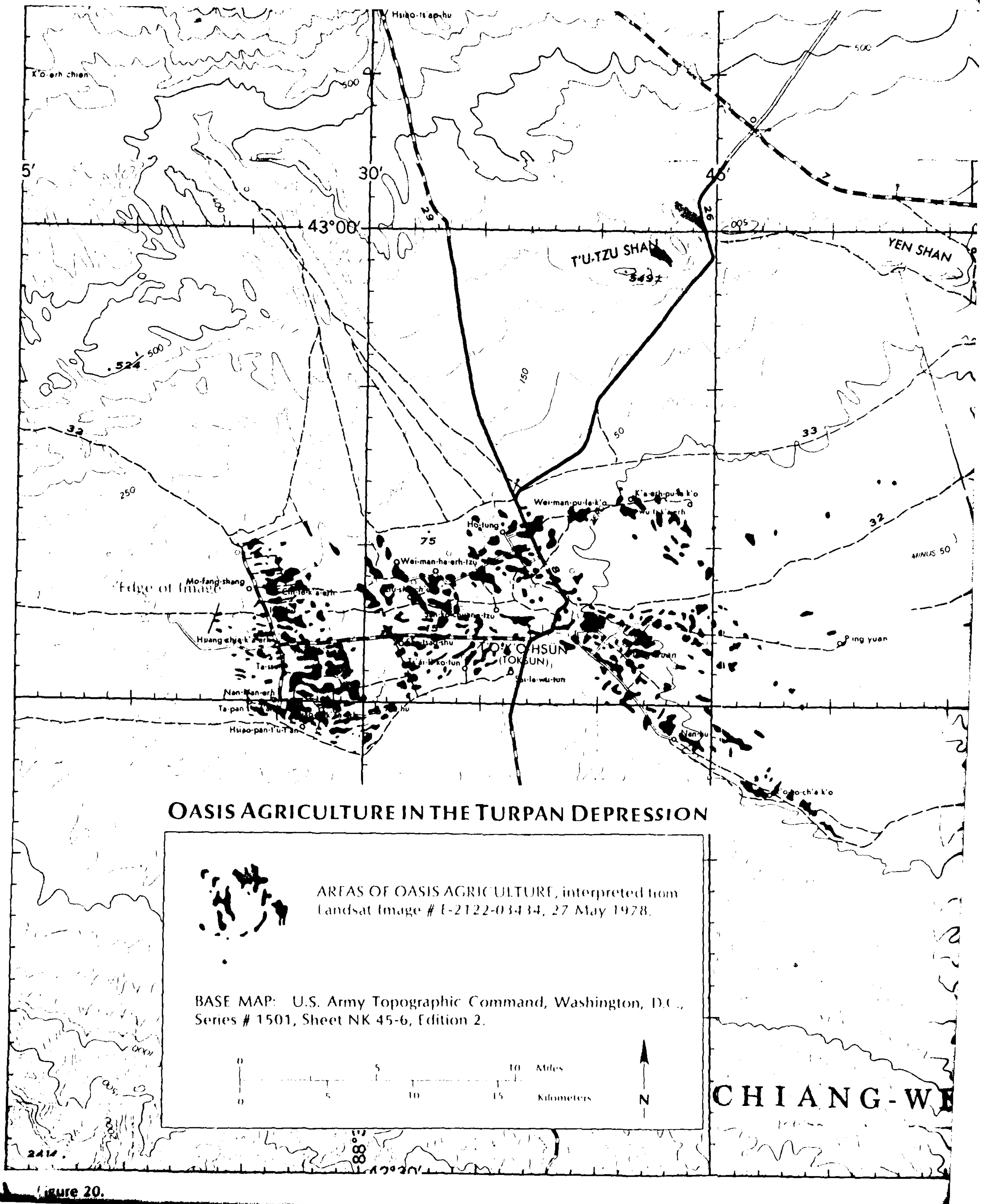


OASIS AGRICULTURE IN THE TURPAN DEPRESSION



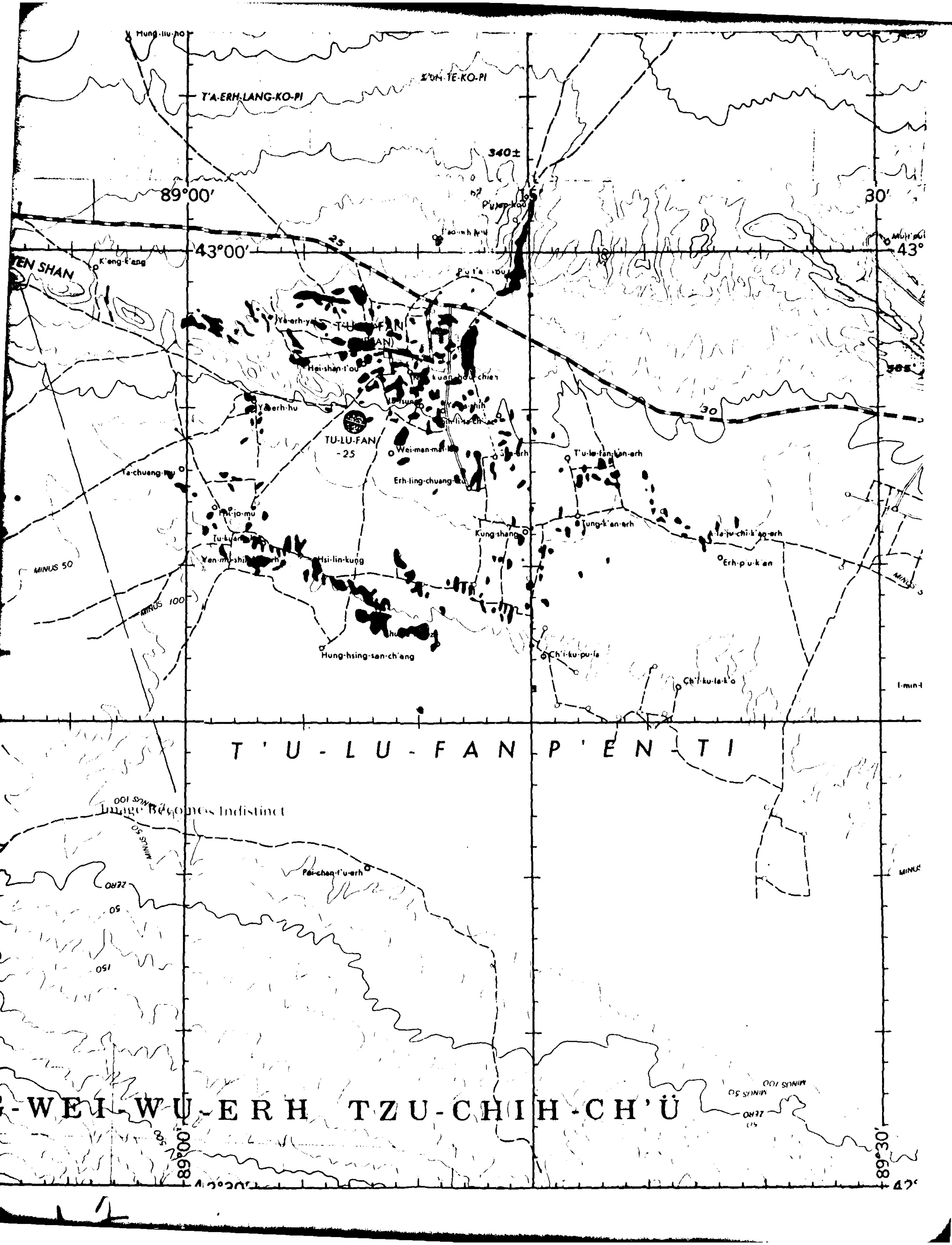
SINKIANG RAILWAY
Huo-yen-shan
90°00'
45'
43°00'
Mu-erh-t'u-k'o
HUO YEN SHAN
Sheng-chin-t'ai
Erh-p'u
San-p'u
T'u-yu-kou
Lien-mu
Yen-k'o-erh
Han-t
San-tao
Yang-ha
I-min-k'an-erh
Pei-ch'u
345
610
500
350
ZERO
MINUS 100
MINUS 50
Sha-ch'ih-wang-k'an-erh
Hu-ya-tzu-k'an-erh
Ta-lang-k'an
T'i-k'an-erh
SHA
KUM
TRANSVERSE DUNES


OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-2 968-03353, 16 Sept. 1977
BASE MAP: U.S. Army Topographic Command, Washington, D.C.
Series # 1501, Sheets NK 46-4, Edition 1, and NK 45-6, Edition 2
Miles
Kilometres
N
LANCHOW SINKIANG RAILWAY
Hung shan kou
15'
30'
45'
43°00'
90°30'
SHAN-SHAN
381
580±
598
620±
672
STAR DUNES
SANS-SHAN
KUM TAGH
KIAN
Santshih-li-ta-tun
Ta-shih-tou



OASIS AGRICULTURE IN THE TURPAN DEPRESSION
AREAS OF OASIS AGRICULTURE, interpreted from Landsat Image # E-2122-03434, 27 May 1978.
BASE MAP: U.S. Army Topographic Command, Washington, D.C., Series # 1501, Sheet NK 45-6, Edition 2.
0 5 10 Miles
0 5 10 15 Kilometers
N
Edge of Image
T'U-TZU SHAN
YEN SHAN
T'O-K'O-HSUN
(TOKSUN)
Hsiao-ts'ao-hu
K'o-erh chien
Wei-man-pu-la-k'o
Ho-tung
Wei-man-ha-erh-tzu
Mo-fang-shang
Huang-chia-k'a-erh
Nan-Man-erh
Ta-pan
Hsiao-pan-t'u-t'an
Sai-le-wu-tun
P'ing yuan
MINUS 50
CHIANG-WE
43°00'
42°30'
30'
45'
88°

igure 20.


Hung-liu-ho
T'A-ERH-LANG-KO-PI
TE-KO-PI
340±
89°00'
30'
P'u-ya-kou
43°00'
43°
TEN SHAN
K'eng-k'eng
25
30
T'U-LU-FAN
Hei-shan-t'ou
Ya-erh-hu
TU-LU-FAN
-25
Wei-man-mai-li
Ta-chuang-tzu
Erh-ling-chuang-tzu
T'u-le-fan-k'an-erh
Tung-k'an-erh
Kung-shang
Erh-p'u-k'an
Hsi-lin-kung
MINUS 50
MINUS 100
Hung-hsing-san-ch'ang
Ch'i-ku-pu-la
Ch'i-ku-la-k'o
I-min-
T ' U - L U - F A N   P ' E N - T I
Image Becomes Indistinct
MINUS 100
MINUS 50
Pei-chen-t'u-erh
ZERO
50
150
MINUS 100
MINUS 50
ZERO
G-WEI-WU-ERH TZU-CHIH-CH'Ü
89°00'
89°30'
42°30'

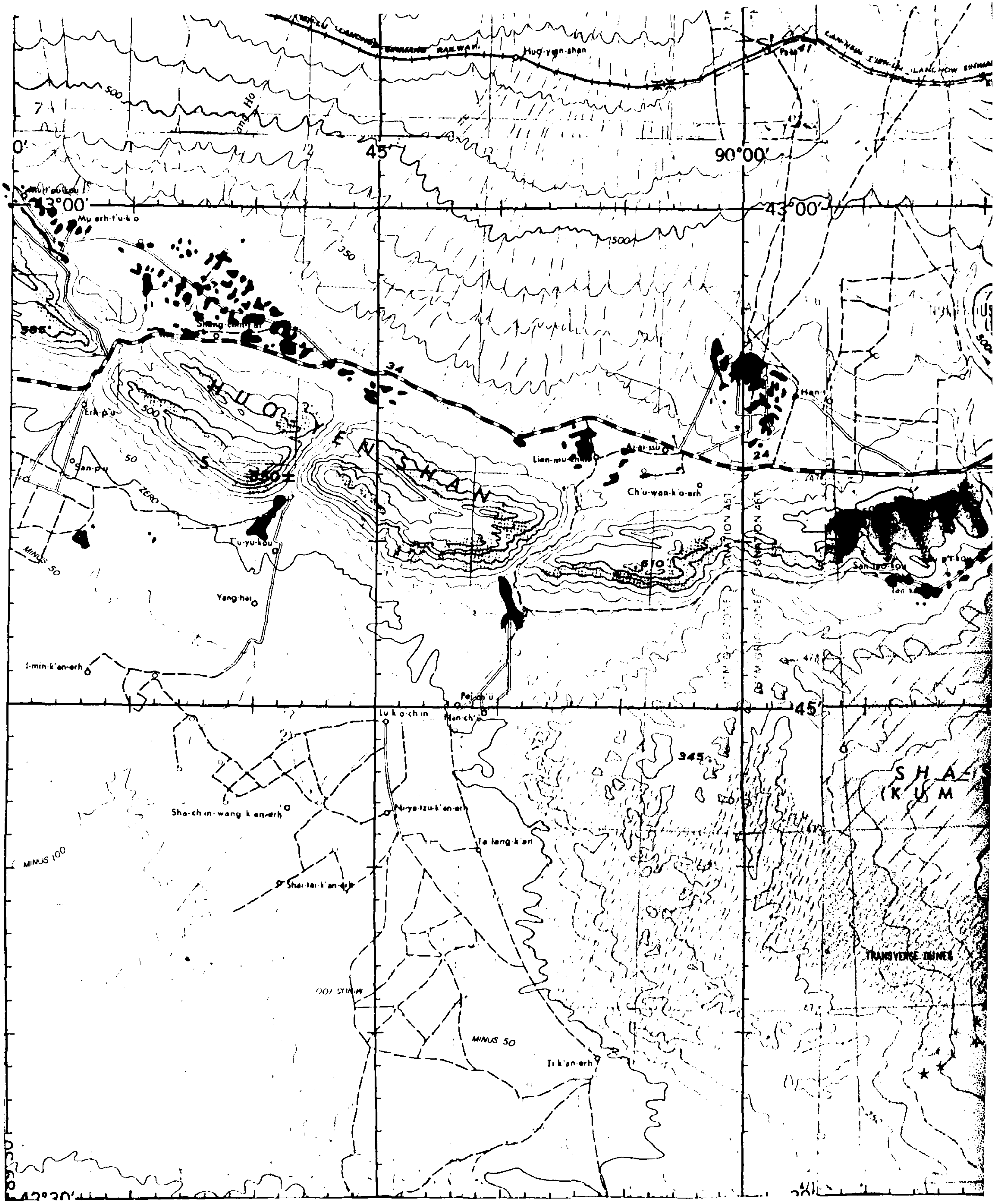
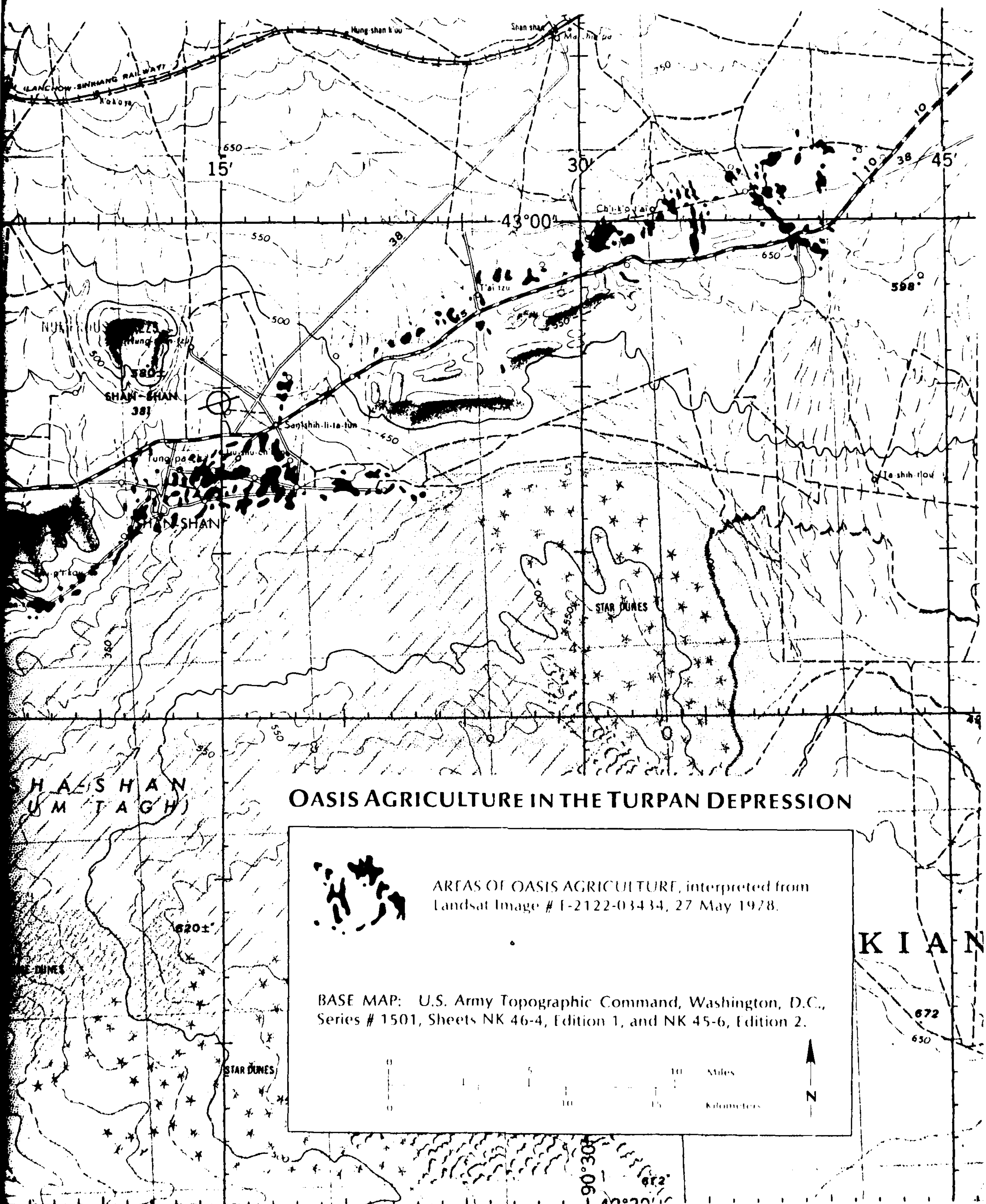

Huo-yen-shan
90°00′
45′
43°00′
Mu-erh-t'u-k'o
Sheng-chin-t'ai
HUO YEN SHAN
Erh-p'u
San-p'u
500
350
50
ZERO
MINUS 50
T'u-yu-kou
Yang-hai
I-min-k'an-erh
Lien-mu-ch'in
Ch'u-wan-k'o-erh
Han-t
610
345
Pei-ch'u
Lu-k'o-ch'in
Han-ch'e
Sha-ch'in-wang-k'an-erh
Ni-ya-tzu-k'an-erh
Ta-lang-k'an
MINUS 100
Shai-tai-k'an-erh
MINUS 50
Ti-k'an-erh
SHA
KUM
TRANSVERSE DUNES
42°30′

Figure 21.



OASIS AGRICULTURE IN THE TURPAN DEPRESSION

1 4

management, areal measurement as well as cartographic information is important. Therefore, the use of Landsat imagery for oasis agriculture mapping and measurement will be examined in the remainder of this study.

E. Calculation of Oasis Agriculture from Landsat Data

No tests were made to determine the accuracy of individual Landsat scenes. It was assumed that the images were a cartographically accurate photomap and that their internal geometry was within the standards prescribed for maps at publication scale. Any errors in visual measuring and mapping of oasis agriculture from imagery should be attributed to factors other than geometric and planimetric abberations within the Landsat imagery.

As previously mentioned, the area grid of .01 square inch cells was used to make all area estimates. The aggregate percentage estimate of all the cells that covered oasis agriculture was then multiplied by square feet/acre equivalent per cell at the designated Landsat scale. This calculation gave the total area of the oasis agriculture measured within the study area on the Landsat imagery. At the Landsat scale of 1:250,000 each one inch square cell grid contained 20,833.3 square feet or 9,963.9 acres.

As Table VII indicates, the total acres of oasis agriculture decreases with time according to the grid cell estimation procedure. Several underlying factors, both positive and negative must be considered when making an anlaysis of this table. They are: (1) scale, (2) ease of oasis agriculture identification and measurement, and (3) the importance of tonal signature contrast and image clarity.

TABLE VII. AREA ACREAGE CALCULATIONS OF THE TURPAN DEPRESSION

Date of Imagery	Total of 1-Inch Sq. Cells	9,963.91 acres/ square inch	One Acre = .405 Hectares	One Mow = .067 Hectare or .165 acres	Percent of Study Area within the Image Scene
4 Oct 1972	9.895 in^2	98,592.88 ac	39,930.11 ha	595,971.79 mow/ha 597,532.60 mow/ac	100%
26 May 1973	6.418 in^2	63,948.37 ac	25,899.08 ha	386,553.43 mow/ha 387,565.87 mow/ac	95%
1 June 1977	5.8475 in^2	58,263.96 ac	23,596.90 ha	352,192.53 mow/ha 353,114.90 mow/ac	97%
16 Sept 1977	3.9765 in^2	39,621.48 ac	16,046.69 ha	239,502.83 mow/ha 240,130.18 mow/ha	less than 50%
27 May 1978	3.783 in^2	37,693.47 ac	15,265.85 ha	227,848.50 mow/ha 228,445.27 mow/ac	99%

Imagery scale greatly affects the amount of oasis agriculture that can be estimated from area grid measurements of Landsat data. There is greater opportunity for precision in visual estimation from the 1:250,000 scale imagery since the ratio of area to cell size is larger than at 1:1,000,000 scale. This is considered a plus when making an estimation of the accuracy of the thematic maps.

Another factor associated with scale and cell estimation is the size and configuration of the oasis agricultural areas that are identifiable on the Landsat imagery. At 1:1,000,000 scale, small or scattered oasis agriculture parcels are more difficult to detect than at the enlarged 1:250,000 scale. When mapping these oasis agricultural areas at 1:250,000 scale the probability of a greater percentage of oasis agriculture cell estimation error will occur at this scale because of the many small parcels to be measured, which can compound the error percentage.

Image sharpness is an additional factor which influences the value of the Landsat areal percentages of accuracy. Despite the decrease in edge sharpness at 1:250,000 scale, a substantial visual error of addition or deletion in mapping oasis agriculture would not significantly affect the percentage of accuracy in comparison to what might be experienced at the mapping of 1:1,000,000 scales. At 1:250,000 scale acutance of Landsat imagery is poor in contrast to the 1:1,000,000 scale data; details are "fuzzy" and tonal signatures are difficult to separate. Small, scattered oasis agricultural lands are detectable on the 1:250,000 scale imagery, but the actual measurements of these parcels will be affected by the reduction in image clarity. Although edge sharpness of Landsat imagery is improved at 1:1,000,000 scales, oasis agriculture parcels are smaller in size, and, therefore, would be more difficult to detect and measure.

Perhaps the greatest drawback to utilizing visual interpretational techniques for measuring and mapping the oasis agriculture from Landsat imagery is the question of reliability. Coupled with this problem is lack of sufficient and reliable information that can be used for comparing the acreage estimations that were made from 1:250,000 Landsat data.

In evaluating land reclamation efforts in this area, based on the scant literature available, it can be modestly stated, that from 1972 through 1978 the agricultural area should have increased slightly. This general assumption is based on the following reasons. (1) Improvements in irrigation measures plus an increase in number of canals and wells built, Table II. (2) An increase in planted area--even though Table III only provides very superficial information it does state that planted areas for grapes, melons, and wheat have increased. It should be noted that quite probably pre-communist figures for cultivated acreage were under-enumerated by landowners to escape taxation, whereas there is less incentive and opportunity to do this under a collectivized system. Hence, figures for increased acreage after the communist takeover may well be exaggerated for political reasons. The reported amount of acreage increase is so slight and not comprehensive for the whole of the Turpan basin that it is unrealistic to venture a guess of the total acreage of agriculture in the basin based on this information alone. (3) Since forest belts were considered a part of the agricultural definition they must be mentioned here. Table V states that in 1972 Turpan County had 40,000 mows or 2,666 hectares of shelter belts. No figures were given for either Shanshan or Toksun counties. An overall impression of Table V is that establishment of windbreaks is being carried out at an increasing rate for protection of farmland. Percentages of forest belts reflected in the total acreage of oasis agriculture might be speculated to be approximately ten percent. Based on these assumptions, the oasis agriculture should have increased slightly or at least remained the same in total acreage but that was not the case relying only on imagery interpretation. It should be noted that the study area within each frame is not 100 percent (Table VII), therefore, reflecting acreage estimates that are not wholly comparable with one another. What they do show is the biggest possible difference in acreage between years.

First, a very important aspect must be considered, and that is seasonality. Scrutinizing all thematic maps (Figures 13-21), it becomes apparent that even though there are no drastic or obvious visual changes in pattern or location of the oasis agriculture parcels, what does stand out is the difference in density of the oasis agriculture pattern. This is considered to be an aspect of seasonality (Figures 13-14--04 October 1972, and Figure 10--16 September 1977), the fall images reflect a higher density in the oasis agriculture pattern than is visible on the late spring images (Figures 15-16--26 May 1973 and Figures 17-18--01 June 1977) which are characterized by less dense and more dispersed patterns. This noticeable increase in density on the fall images can be attributed to plant density, stage of growth, and vigor of the vegetation which affects the level of infrared reflectance recorded by the sensor. Unfortunately, phenological data (the basis for "crop calendar") are not available for the crops grown in this area, therefore, based upon normal crop maturity over the growing season it can be logically stated that the result of an increase in the density of the oasis agriculture is an aspect of seasonality even though the magnitude of phenological variation are not known for this particular area.

To determine a percentage of accuracy per se in area acreage estimates and for mapping procedures will not be possible because of the lack of known acreage figures and ground data. What can be done, however, is to evaluate the level of consistency in mapping and area calculations, and its interrelationship with the problem of image resolution.

In evaluating consistency, an identical small parcel of oasis agriculture was selected on all images, being of the same size and same location. By subjective visual inspection, the resolution of the parcels differed (but not by extremes) on all four images used, 04 October 1972, 26 May 1973, 01 June 1977, and 16 September 1977.

Measuring the selected areas on the Fall 16 September 1977 contact paper proof and the 04 October 1972 contact paper proof, it was found that for 16 September 1977 the area increased slightly by 0.056 in^2 or 557 acres. Measuring the selected areas on the late Spring 01 June 1977 contact paper proof and the 26 May 1973 contact paper proof, it was found that for 01 June 1977 the area decreased slightly by 0.835 in^2 for 831 acres. To further evaluate level of consistency in mapping and area calculations, the next step employed was a repeat interpretation (utilizing the zoom transfer scope) of the exact same area, drawn from the 16 September 1977 and 04 October 1972 images. After the interpretation was done, the same transparent area grid was utilized for the area calculations and these measurements were then compared to the original measurements. The repeat measurement for 16 September 1977 was 0.9995 in^2 an increase of 0.136 in^2 or 1,355 acres over the original 16 September 1977 measurement of 0.8635 in^2. The repeat measurement of 04 October 1972 was 0.907 in^2 an increase of 0.0995 in^2 or 991 acres over the original 04 October 1972 measurement of 0.8075 in^2. For 04 October 1972, an 11.6% consistency/error factor based on areal measurements and the interpretation between original and repeat calculations was determined. For 16 September 1977, a 14.6% consistency/error factor based on areal measurements and interpretation between the original and repeat calculations was determined. Averaging these two percentages together, the overall value of consistency in thematically mapping and measuring the oasis agricultural lands might be stated as approximately 13 percent. To further evaluate the consistency in the area measurements, a disinterested person was employed in measuring the same select areas on the contact paper proof for the two fall images of 04 October 1972 and 16 September 1977. It was found that the area calculations utilizing the same transparent grid only differed by 5 percent. This last test gives additional credence to the consistency/error factor of 13 percent for the mapping of the oasis agriculture in the Turpan Depression.

Since the fall images show an increase in acreage from 1972 to 1977 and the late spring images show a decrease in acreage from 26 May 1973 to 01 June 1977, it is apparent that no absolute answer can be given as to yes there has been an increase in acreage of oasis agriculture, or no there has not been an increase in acreage of oasis agriculture, or the acreage of oasis agriculture has remained relatively stable. Careful inspection of thematic map patterns does not even lead to a better assumption than is already given above. What can be comfortably stated is: (1) given a longer time frame for analysis, (2) accurate, and supporting materials and ground truth, and (3) images of excellent resolution, then, based on these three important factors, it should enable the interpreter to make a committal decision as to whether there has been an increase, decrease, or no change in the oasis agriculture of the Turpan Depresstion. But of these factors, access to ground data or reliable statistics is the most important factor.

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CHAPTER V

CONCLUSIONS

The objectives of this study have been to thematically map oasis agriculture, estimate total acreage under oasis agriculture, and assess agricultural land reclamation efforts within the Turpan Depression using Landsat imagery. The following is a summary of findings that were developed in the course of the investigation.

Simple, manual techniques were utilized in interpretation, mapping and measuring phases of the study. As results of the study indicate, Landsat imagery is a good medium for detecting, identifying, measuring, and mapping oasis agriculture. The degree of cartographic and measurement consistency that could be attained from Landsat using visual methods, however, depended upon two interconnected criteria: (1) the interpretative qualities of Landsat data, such as the edge sharpness, and scale of the MSS imagery, and (2) the skill of the interpreter.

As the description of Landsat imagery in the study illustrates, color composite imagery was assumed to be more useful for oasis agriculture delimitation and mapping in comparison with normal black and white or infrared data because of its false-color properties. The color displayed by oasis agriculture (dark red) is distinctive and greatly enhances its detection from the satellite data.

Paramount in importance as characteristics which affect visual mapping and measurement of oasis agriculture from Landsat imagery are scale and edge sharpness. At the enlarged 1:250,000 scale clarity of oasis agriculture on Landsat imagery is less sharp than at 1:1,000,000 scales, but there is more tolerance for aberration and a greater opportunity for cartographic and measurement precision than possible at smaller scales. Although delimitation of oasis agriculture is directly tied to spectral characteristics and scale of the data, accurate oasis agricultural maps and measurements cannot be obtained unless the imagery is planimetrically reliable. No planimetric tests of the study's Landsat imagery data were done. It was assumed that the imagery met or approached National Map Accuracy Standards. Based on this assumption, then, Landsat MSS data imagery was a reliable photomap for the thematic mapping of oasis agricultural lands in the Turpan Depression.

Despite the importance of image quality and scale, one other factor is essential for accurately mapping and measuring oasis agriculture from Landsat data; this is the human element--the perceptive abilities of the interpreter and the choice of an appropriate classification. To utilize visual interpretational techniques for oasis agriculture delineation in the Turpan Depression from Landsat imagery, it was not essential that the interpreter have had extensive training in analysis of remotely sensed data. What was important, however, was that the interpreter be familiar with the study area and its particular characteristics. For mapping oasis agriculture (as defined in this study), the Level I categories of agricultural and forest lands were the optimum classification levels from which to conduct thematic mapping.

Landsat data played the key role in preparing the thematic maps. Only one class of information, i.e., oasis agriculture was extracted because of resolution, and the lack of supporting materials. Landsat data are useful for foreign area studies, but the maximum potential of these data, especially in the case of this study, i.e., to assess the agricultural land reclamation effort can only be mere speculation. To make a valid assessment of the land reclamation effort in this area will have to wait for more published materials by scientific journals, and a longer time sequence of Landsat images. A time sequence of less than 10 years was especially critical to this study. It limited the number of images available, thereby restricting the possible number of comparisons that could be made of the oasis agriculture from year to year. A longer time sequence of Landsat imagery with more seasonal stages would provide the necessary data base from which to monitor agricultural change.

Four main thematic maps were produced from the Landsat imagery, excluding the May 1978 thematic map. June 1977 and May 1973 were considered to be the late spring thematic maps, and October 1972 and September 1977 were considered to be the fall thematic maps. This aspect of seasonality was based on the differences in density of the oasis agriculture pattern, with the fall maps having the more dense patterns as opposed to the spring maps which reflected a more dispersed oasis agricultural pattern.

It was determined from several sample tests, i.e., repeating interpretations and area calculations that the consistency factor in mapping the oasis agriculture of the Turpan Depression was approximately 13 percent.

Lastly, the methodology employed was successful in thematically mapping the pattern of oasis agriculture in the Turpan Depression and determining its estimated acreage from Landsat. The major limitation in this study, which would apply to any similar study of a remote or foreign area, is the problem of procuring substantiating documents to assist in the final analysis of the research problem. Also, the type of technique employed for the mapping of agriculture must be carefully considered. The relative accuracy of any technique would invariably depend on the degree of information you want to extract and for what purpose it will be used. The manual techniques employed in this study were adequate for thematic mapping and area estimations of the oasis agriculture. Most importantly, a better understanding of the pattern of oasis agriculture, and its associated land management problems have been realized from this investigation. The methodology employed here would be suitable for an analysis of an agricultural research problem associated with an arid or semi-arid region where irrigation is necessary, and the delineation of agriculture from its surroundings is relatively easy.

APPENDIX

GLOSSARY

1. catty/chin = one and one-third pound.

2. commune--A large collective organization, which is divided into production brigades and smaller production teams which manage and perform agricultural work and production. The commune as a whole manages repair and construction work, handicrafts and small scale local industries, and has tended to become an organ of low-level administration, with responsibility for law and order, rural education, health services, irrigation and water-control, and local transport.

3. image interpretation--is defined as the act of examining images for the purpose of identifying objects and judging their significance.

4. li = one-third mile.

5. mow = .067 hectare; or .165 acre.

6. NASA--National Aeronautic and Space Administration.

7. NCNA--New China News Agency, headquartered in Beijing, the NCNA English-language news releases generally total over 12,000 items per year.

8. remote sensing--In the broadest sense, the measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study.

9. thematic maps--Maps which concentrate on the spatial variations of a single phenomenon of the relationship between phenomena.

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