Optical DEM generation: satellites help preserve Przewalski's horse

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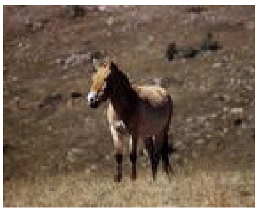


Key words:
Przewalski's horse, Hustain Nuruu, DEM, optical DEM, geocoding, geocorrection, georeferencing, MACNE, SPOT, Landsat TM, GIS, Mongolia.

Abstract:
Privateers NV generated a DEM from optical LANDSAT TM and Spot images as first layer for the GIS system that is used in the Hustain Nuruu national park in Mongolia by the re-introduction program of the Przewalski horse.

Parbleu! ... What horse?

The only wild horse in existence is *Equus przewalskii*, or *takhi* as the Mongols call it. The domestic horse has 64 chromosomes, Przewalski's horse has 66. From Bouman (1986) we learn that: "In 1879/1880 Colonel Przewalski made his third trip into Central Asia, and this time he did discover two herds of wild horses, which fled as soon as they saw him. In scientific circles it is customary that a newly discovered animal or plant be given the name of its discoverer, and thus this wild horse from Mongolia got its name of 'Przewalski Horse'. Some years later the brothers Grum Grshimailo, a couple of Russian hunters, explored Central Asia. They probably have been the first to see Przewalski-horses in the wild. Przewalski's observations seem to indicate that he saw wild asses instead of wild horses. Grum Grshimailo shot Przewalski-horses. The skulls and hides of these were also taken to Petersburg, investigated there, and once again the conclusion was, that they were from wild horses, and that consequently these had not died out, but still existed." The image shows Colonel Przewalski.

Przewalski's horse became extinct, save for animals kept in parks and zoos. Over the last twenty-five years a rehabilitation program has worked hard to reintroduce the species in the wild. This program is the private initiative of the Bouman family, who set-up various foundations to help organize the work and fund-raising, together with MACNE, the Mongolian Association for the Conservation of Nature and the Environment. A careful breeding program was initiated and a selection of horses was set free in semi-reserves in Western Europe. There they developed the natural social behavior, a matter of life and death for survival amongst the wolves in the steppes of Mongolia. A carefully planned reintroduction program brought a selection of Przewalski's horses to the Hustain Nuruu mountain forest and steppe reserve, that has meanwhile received the status of a national park (Bouman, 1997). Around 150 horses now roam free, produce offspring and have fared remarkably well during a number of very severe winters. The animals are carefully monitored and the project is highly successful. So far, this is arguably the only successful reintroduction program worldwide. The image shows Ranger Dorjürev.

In 1998, Treemail was contracted to help the foundations with setting-up a home page that serves as first port of call to anyone who seeks information on Przewalski's horse (Treemail, 1998, and Romeijn *et al.* 2000). In his personal letter of introduction to this home page H.R.H. Bernhard, Prince of The Netherlands and former President of WWF, writes the following on the hard work of the Bouman family: "Having followed their commitment over many years I personally feel that the work of the Bouman family is one of the best success stories in the field of nature conservation" (Lippe Biesterfeld, 1998). The image shows the release of one of the Przewalski's horses: Free at last!

Introduction of a GIS system

A geographical information system, or GIS, was introduced in the project by CSO consultants for environmental management of The Netherlands in 1996. A report on this introduction was written by Hoogerwerf and Van der Meulen in 1997. In the section 'recommendations', these authors assert that: "it is of utmost importance that the quality of the digital geographical databases compiled so far should be checked and documented. Errors should be removed. A start was made in 1996 but problems still have to be resolved. The most important unresolved problems are the classification methodology of the soil map and the problems in matching the different basemaps due to lacking of informations about mapprojections" (CSO, 1997).

In the same report of 1997, Hoogerwerf and Van der Meulen write: "In the digitizing process, essential background information about the mapprojection of the original paper maps has not been recorded. As the original paper maps have appeared to be lost or not been recoverable from other institutes, it will be hard to recover essential information on the mapprojections and projection parameters used on the original maps. As the source maps had different map projections and projection parameters, it has not been possible to match the digital versions of several maps. [...] Boundaries that should coincide are sometimes several hundreds of meters apart, although both maps were compiled on the basis of the same topographical map" (CSO, 1997).

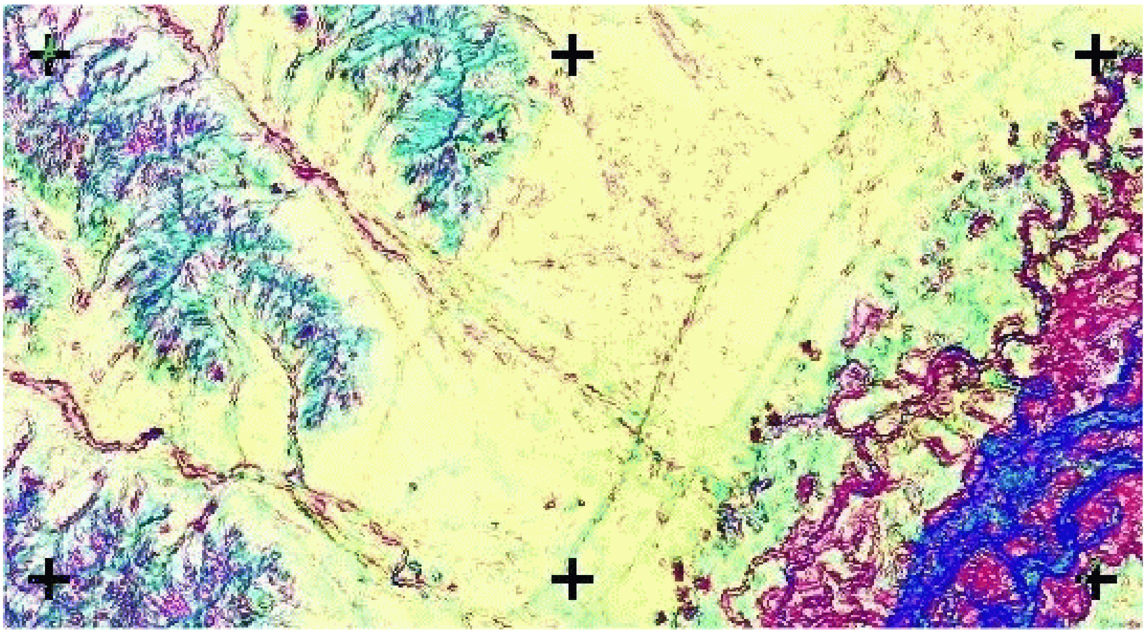
Desktop GIS Arcview was installed by CSO on the basis of these digitized basemaps. The local coordinate system that had been used for wildlife and vegetation studies was converted to a theme in Arcview to enable spatial queries. The disadvantage of the system used is the fixed spatial resolution of 500 m used in data recording. If the recording of x,y positions could be done more accurately in the field [... this] will result in more accurate analysis and display of the research data (all *ex.* CSO, 1997, p9). The precise correlation of this spatial resolution with the above cited discrepancies of "sometimes several hundreds of meters" remains unclear in said report; at least to the present authors that is. Such discrepancies preclude the sensible use of GIS as a tool for investigation and display of, e.g., relationships between vegetation types, elevation and GPS records of field observations. Anyway, recorded data are entered in a meta-information sheet according to CSO (1997). An example of a meta-information sheet is included here in Annex 1.

Enter the satellite images

A distance of a few thousand kilometers does not always provide the most favorable camera position. Yet, with satellite images such realities cannot be ignored if one aims to provide usable products. To quote Treebook 8 (Vester *et al.* 2003): "Spaceborne images suffer from deformations, made by the convex shape of the earth, rugged terrain, mountains, different instruments (e.g., radar, infra-red, optical) or camera positions or resolutions (when working with multi-temporal images), to name but a few. At Privateers NV, the problem of how to fit the pixels from different satellite images precisely on top of each other has been largely solved, witness the highly accurate contour maps of Southern Ethiopia that were made to help research the Gedeo land-use system (Kippie *et al.* 2001). This allows for proper pre-post analysis of major catastrophes, including earthquakes and hurricanes, given the proper processing software that is. Now that this quality has been combined with speed, the satellite image processing operations can follow events in near real-time (as reported in, e.g., Nezry *et al.* 2001, and BBC, 2001, for the case of an earthquake in El Salvador)". All this would be experienced -once more- within the context of the project for the reintroduction of the Przewalski horses.

A SPOT 4 scene of reasonable quality was acquired by the project in 1999. It was bought with the intention to provide a basemap for inclusion into the GIS. Without proper georeferencing and geocoding, however, this goal remained elusive and the central problems persisted. At some point in time the work on the GIS had been transferred from CSO to Alterra, also of The Netherlands. It surfaced that the SPOT 4 images were never referenced to GPS ground control points. This not only left the discrepancies of 'several hundred meters' intact, in fact it added a few more of its own (Bouman and Wit, personal communication, 2000-2002) and this confounded proper linkage of GPS referenced field observations to the GIS even further. The project then took up contact with Privateers NV, to help sort out the mess.

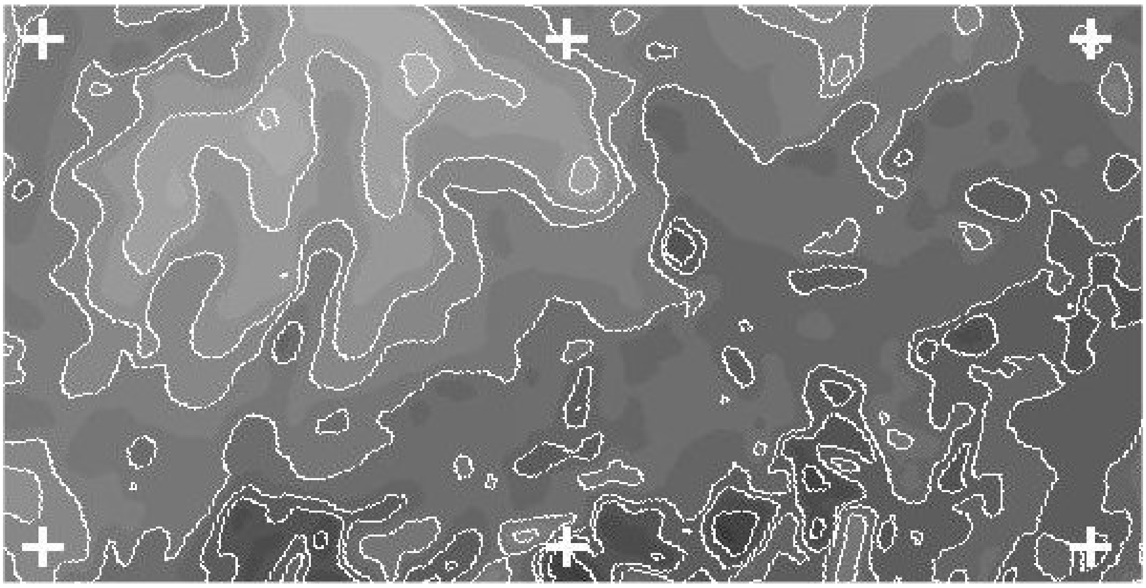
At Privateers NV's lab the SPOT 4 scene was geocoded and georeferenced (and presented in Universal Mercator Projection, Zone 78, Krassovsky 1940) with the company's propriety software and with the help of 4 GPS control measurements taken by project leader Piet Wit. Privateers NV's Dr. Francis Yakam processed the images into a thematic map that displays major and minor waterways, and a combination of vegetation and soil indices and pattern detectors. Special attention was given to the presentation of this map so as to enable easy recognition by untrained personnel. The map displays the minor (in dark blue) and major (in purple) beds of the river, the entire hydrological network, the dirt-road tracks (as green lines) and the agricultural fields. The image displays a sample of this map; the grid is 5x5 km.



A Landsat 5 TM quarter-scene surfaced in 2002. This image had been acquired at an early stage of the project, in 1990, but it had apparently gone missing by 1997. At that time, CSO concluded: "it is not known if the Landsat images [...] are still available" (CSO, 1997). The scene had been deprived from its header files for reasons unknown to the present authors. Header files contain vital information on the satellite position and orientation of the sensors at the time of the image capture. They constitute an integral part of a scene, so much so that Landsat 5 TM scenes without header files are actually sold at a different (lower) price. Loss of header information is generally considered as a fatal blow to any hope to proper geocoding and georeferencing. This was the crux of the case at hand precisely, because: "Correct and consistent topology of the geographical database is essential in the effective use of the database in GIS" (CSO, 1997). Yet, with the good cause of improving the Przewalski's horses fate in mind, the Privateers NV team decided to remain unperturbed and to press ahead with the preparation of an optical DEM without the requisite header files. In this case, satellite orbit data and sensor characteristics were used in order to restitute the Landsat 5 TM acquisition parameters.

The optical DEM

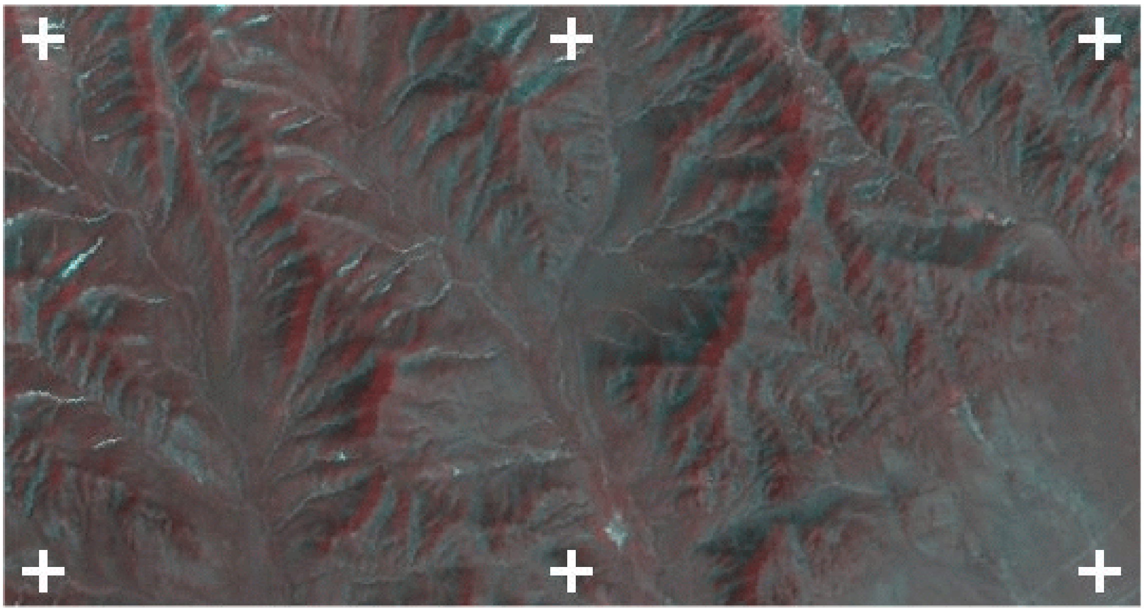
The Landsat 5 TM quarter-scene is entirely cloud-free. It easily covers the entire project area, including the areas bordering the Hustain Nuruu reserve. The useful overlap with the SPOT 4 scene is well over 3,000 km^2. The SPOT 4 scene is essentially cloud-free, save for a few clouds that are well away from the areas of interest to the project. At Privateers NV's lab, Dr. Edmond Nezry processed the overlapping Landsat 5 TM and SPOT 4 scenes. A contour map and an anaglyph for 3-d viewing were produced, both geocoded and georeferenced. The image shows a section of the contour map; the grid is 5x5 km, the contour lines are at 100m intervals.



The '100% loss free .jpg' file format of these maps is fully compatible with all standard GIS software. Advantages of using these maps as a source basemap of the GIS are manifold. In hydrology, flow paths can be modeled and clearly marked and catchment areas determined. Areas susceptible to erosion can be easily detected using grid based models that include slope, slope length, aspect and soil characteristics as input sources. Visibility analysis is another area that uses the DEM as input. This can aid identification of preferred locations for observation posts and help evaluate current and possible migration routes. The use of a DEM can also add to the analysis of vegetation data, enabling investigation of relationships between vegetation types and elevation (all *ex.* CSO, 1997, p 9-10).

Moreover, the file format allows the maps to be readily imported and manipulated in commercial image viewing packages such as Paint Shop Pro®. Versatility is of special importance to personnel not familiar with the manipulation of GIS software and ensures compatibility over different platforms (e.g. Linux, Unix and PC). This has proven to be invaluable to the success of an earlier, similar mapping project that was done in support of a PhD study for the University of Wageningen, The Netherlands, on the land-use system in the Gedeo Highlands of Southern Ethiopia (Kippie Kanshie, 2002). Such versatility reduces the need for highly trained personnel that is associated with complex GIS software because one avoids problems of quality control and circumvents the complexities associated with import and export of information between, say, ArcInfo® and ArcView® or AutoCad®. The reader is referred to Annex 5, 6 and 7 of the CSO report of 1997 for a further description of these and a number of other problems associated with file-management in the Hustain Nuruu GIS.

The quality of the fit that has been achieved between the Landsat 5 TM and SPOT 4 can easily be appreciated by studying the anaglyph. The information derived from the 1990 Landsat TM scene is projected in red, that of the SPOT 1999 in blue. A pair of red (left-eye) and green (right-eye) stereo glasses is mandatory for proper viewing of this map. The image shows a section of the anaglyph; the grid is 5x5 km.



It is relevant to note the large time lap of nine years between capture of the Landsat TM 5 and the SPOT 4 scenes. According to the Swiss Federal Institute of Technology: “it happens that optical images suffer from large radiometric differences especially between images taken in a long time interval (temporal decorrelation). Every difference in radiometry is able to corrupt the correlation and so false the measure of parallax. This causes an augmentation of noise pattern in image correlation, and affects the height estimation” (Renaudin, 2000). However, despite this time lap between the two images, for the project area the Privateers NV DEM and anaglyph hardly suffer from these defects thanks to the quality of the Privateers NV processing software.

To the contrary, changes to the landscape that occurred during the 9 year lap are displayed clearly on the current maps. These changes can be detected and visualized by studying the anaglyph with the left and right eye alternately. One can readily observe, e.g., changes in the positions of nomadic dwellings, changes in orientation of mechanical preparation of the agricultural fields, the opening up of new agricultural fields and the abandonment of others. A number of changes that are caused by sedimentation, erosion and the shifting of sand dunes can also be visualized in the same way, too. It is perhaps reassuring for the Przewalski’s horse reintroduction project that the most striking of these changes are only observed outside of the Hustain Nuruu reserve displayed in this document.

A note on prices

At the Swiss Federal Institute of Technology, the typical price of "a SPOT DEM in a 20m grid [...] and an orthoimage in a 10m grid [...] is around **13,100 €** for a 3,000 km^2 scene without clouds. In the case of bad measurements, clouds or big radiometric differences, programming cost will be higher, and so the price can reach **18,000 €** or more" (Renaudin, 2000). Due to the difference in pixel size between the two sources, processing a combination of Landsat 5 TM and SPOT 4 scenes into a DEM is more complicated and time consuming. However, in our experience, these prices must remain entirely unjustifiable, when the image processing is done with the Privateers NV propriety software.

A note on quality

The compounding of problems that is associated with introducing GIS with poor basemaps is well known. After all, "the purpose of information is to reduce uncertainty in management and decision making" (De Man, 1998). Ian Haynes of the Natural Resource Institute, UK, in a keynote address during a seminar on the role of remote sensing and GIS for development, puts it like this: "The challenge for remote sensing and GIS is to produce results that are reliable, understandable and persuasive enough to influence the decision making process. If these criteria are not met, remote sensing and GIS as tools for sustainable development are unlikely to become best sellers in developing countries" (Haynes, 1996).

And a final note

As a concluding remark, the personal letter of introduction to the Przewalski's horse home page from H.R.H. Prince Bernhard is cited once more: "I do hope that the viewers who read these pages will give the Wild Horse project in Mongolia their wholehearted support by providing the means to support this exemplary project in the coming years" (Lippe Biesterfeld, 1998). The image shows H.M. Queen Beatrix, H.R.H. Prince Bernhard, Mrs Bouman and Mrs Groeneveld at the bestowal of the Silver Carnation award in the Royal Dam Palace in Amsterdam.

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Ref: <http://www.treemail.nl/download/opto01a.pdf> (Note: size is 475 kb).

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Ref: <http://www.treemail.nl/download/treebook5.pdf> (Note: size is 7.3 Mb).

Lippe Biesterfeld, B.L.F.E.J.C.K.G.P. zur; April 1998. **Letter of introduction to the Przewalski horses website.** Soestdijk Palace, The Netherlands. Available online at: <http://www.treemail.nl/takh/images/bernhard_brief.jpg>.

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Ref: <http://www.treemail.nl/download/opto01b.pdf> (Note: size is 650 kb).
Ref: <http://www.treemail.nl/privateers/elsalvador> for images of these damages.

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Notes:

Compromises that were made during archiving and format conversions influence the quality of the images on display; they are shown here at a slightly degraded resolution.

<http://www.treemail.nl/privateers>

Annex 1

Meta information sheet (CSO, 1997).

Annex 4.: Example meta-information sheet

Hustain Nuruu - ICC meta-information sheet

Date:28 december 1996
Author: Marc Hoogerwerf

General information:

Name of the dataset: HUSDEM
Current version: 1.0
Dataset type (ArcInfo, ArcView, AutoCad, image + satelite, dBase, ASCII etc.): Arc/Info
Short description of the dataset: Digital Elevation Model derived from contourlines and elevation points, using the TOPOGRID algorithm in Arc/Info
Type of geographical features (point, line, polygon, grid, regions, tin): GRID
Fysical name of the dataset: HUSDEM
Fysical location of the dataset: c:\arcview\basemaps\husdem
Creator (name and organisation): Tserendolgor and Marc Hoogerwerf at ICC
Creation date: july 1996

Detailed information:

Boundaries of the dataset:
X-min: 1621112.151012
Y-min: 841177.874368
X-max:
Ymax:
Cell-size for grids / images: 50 meter
Number of rows and colums for grids: 800 x 1141

Projection: Unknown
Spheroid: Unknown
Projection units: Unknown
Projection parameters: Unknown

Map units: meters

Names of related tables: None

Description of feature attribute tables:

Table name:not applicable

Item	Definition	Description
not applicable		

Description of related tables:

Table name: not applicable

Item	Definition	Description
not applicable		

Original paper map:

Map title: unknown
Name of map publisher: unknown
Original mapscale: 1:25.000
Projection: unknown
Spheroid: unknown
Projection units: unknown

Projection parameters: unknown

Digitizing history:

Type of software used for first digitized version (AutoCad, ArcInfo, ArcView): Autocad
Organisation and person: Unknown
Creation Date: unknown
Projection: unknown
Spheroid: unknown
Projection units: unknown
Projection parameters: unknown

Quality control history in ArcInfo:

Please indicate if following checks have been completed
Check for dangling arcs (overshoots/undershoots): ✓
Check for missing or double polygonlabels: not applicable
Check for uncoded polygonlabels: not applicable
Check for uncoded arclabels: ✓
Check for uncoded pointlabels: ✓

Check for edit masks: ✓
Lookup-tables available for coded items?: None

Update history :

Update activities:

Description: Correction of overlappping contourlines
Organisation and person: ICC, Tserendolgor and Marc Hoogerwerf
Update date: july 1996

Description: Addition of labels to contourlines
Organisation and person: ICC, Tserendolgor and Marc Hoogerwerf
Update date: july 1996

Description: Generating DEM from contourlines
Organisation and person:ICC, Tserendolgor and Marc Hoogerwerf
Update date: july 1996

Description: Correction of labelerrors
Organisation and person:ICC, Tserendolgor and Marc Hoogerwerf
Update date: july 1996

Description: Generating new DEM from contourlines
Organisation and person:ICC, Tserendolgor and Marc Hoogerwerf
Update date: july 1996