Spatially Located Platform and Aerial Photography for Documentation of Grazing Impacts on Wheat

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Spatially Located Platform and Aerial Photography for Documentation of Grazing Impacts on Wheat

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Abstract

Goose populations that winter in Oregon's Lower Willamette Valley have increased from 25 000 to more than 250 000 birds in the last 25 years, resulting in heavy grazing of wheat and other crops. To map and document the extent and intensity of goose impacts on wheat fields, we combined rectified aerial photography with both globally positioned ground observations and vertical platform photographs. Aerial photos revealed areas of fields with sparse wheat cover while platform photos documented the cause. We estimated wheat cover in ground level photographs by ratioing red, green and blue digital numbers. From platform photographs we recorded occurrence of grazing (from grazed leaf tips), intensity of grazing (from residual plant cover and leaf length), and other indicators of goose use (footprints and droppings). Because the ground photographs were spatially positioned, we could use this information to verify the cause of "thin" wheat. Crop damage from grazing/trampling, water submergence, and other factors was evident. Our results illustrate practical ways to combine aerial and ground-level image analysis, spectral observations, and global positioning systems to quantify field conditions in wheat.

Introduction

Identification of impacts of goose grazing on wheat and separation of these impacts from other factors such as inundation, soil physical properties, soil fertility, and management require data at several scales. Aerial photography is commonly used to monitor crops at field or regional scales more objectively and expediently than ground based methods (Tucker, 1980; Friedl *et al*., 1994; Hall *et al*., 1995). It can show areas of fields with denser wheat stands or more leaf cover. However, finer scale information may be required to assess causality or to suggest remedial practices that improve production.

Various types of ground-based platforms are used to collect detailed remote sensing information. Portable masts and platforms support cameras near ground level to measure vegetative and soil cover (Barrett and Curtis, 1992). With platform or mast photography, it is critical to accurately determine the position of every sample point, both to allow the ground samples to be located on aerial images and to integrate data into a geographical information system (GIS) database. This is accomplished using global positioning system (GPS) technology during photography (Spencer *et al*., 1997). Current technology permits accurate placement of geo-positioned images to within two meters using a 12-channel, L1, C/A-code differential GPS (DGPS) or to within submeter accuracy using phase processing or dual frequency receivers (Trimble Navigation, 1996).

The purpose of this study was to use ground and aerial photography to stratify winter wheat (*Triticum aestivum* L.) fields according to grazing intensity by Canada geese (*Branta canadensis*). In addition, we assessed the time and ease with which platform photographs and corollary information could be collected. These techniques may provide farm managers and agricultural consultants with an objective and replicable means to identify areas with heavy grazing by geese or other factors that result in wheat damage and reduced yield.

Materials and Methods

Study Site Description

Wheat fields included in the study were located on Sauvie Island in Multnomah County, approximately 15 km northwest of Portland, Oregon. The Columbia River, Willamette River and the Multnomah Channel surround the island. The topographically lower northern portion of the island is a wildlife refuge (primarily waterfowl) while the southern half is agricultural/residential.

Soils of the fields included in the study consisted of very deep, poorly drained silt loams and silty clay loams on broad undulating flood plains. They were formed in recent silty alluvium. Slopes are 0 to 5 percent. Soils are generally in the Sauvie series and classified taxonomically as fine-silty, mixed, mesic Fluvaquentic Haplaquolls (USDA Soil Conservation Service, 1983).

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Selection criteria for fields included in the study were: 1), located in an area with anticipated heavy grazing by geese; 2), actively in wheat production; 3), frequently grazed by geese; and 4), managed by farmers willing to cooperate with researchers. Five wheat fields were selected the first year and three the second. Farming practices were similar on all fields but on some fields, farmers aggressively chased and harassed geese to prevent crop damage. Farmers were able to more consistently chase geese off level, open fields close to farm headquarters compared to remote fields with rolling topography. This led to different intensities of use by geese both within and among fields. We constructed goose exclosures which provided ungrazed control plots at nine locations per field. Exclosures were open-topped, 6 m by 13 m areas that were surrounded by poultry netting 50 cm high. Colored flagging was attached to the top of the wire to dissuade geese from landing in exclosures.

Global Positioning Data

In September, after wheat planting, we mapped field boundaries using a Trimble® Pathfinder Pro® XL GPS equipped with a data logger. We logged a minimum of 180 positions at each point where the boundary direction of the field changed. Positions were differentially corrected using a local base station (Portland, OR) and averaged. This information was used to create a mask of the field and to calculate field areas. Distinctive objects in or near the fields were also positioned so they could be used as ground control points to rectify aerial photographs. We placed square white targets (30 cm x 30 cm) throughout the fields the second year and recorded their positions using the GPS. Corrected points were accurately positioned within two meters.

Aerial Photography

We photographed each field three times during the growing season using Kodak® Royal Gold® ISO 400 film in a 35mm camera fitted with a 28mm wide-angle lens, mounted on a single-engine fixed-wing aircraft. Controlled airspace of Portland International Airport restricted flight altitude to 420 m above ground level. We used wide-angle lenses to provide better field coverage at that low flight altitude. A mosaic of the images was scanned and saved as 24-bit tagged image format (TIF) files. These images were imported into Picture Publisher® software and converted into red, green, and blue digital images. Each of these images were then imported into IDRISI®, an image processing/GIS software package (Eastman, 1997). Images were resampled using a minimum of 15 ground control points and a linear, nearest-neighbor algorithm (Richards, 1986). Pixels were resized to 1 m and UTM zone 10, 1983 North American Datum coordinate system. The root mean square error (Richards, 1986) for this operation was kept at less than two meters.

Platform Photography

To obtain higher resolution information at known locations within the field, we constructed a light-weight platform of polyvinyl chloride (PVC) tubing on which we mounted a 35 mm camera fitted with a 28 mm, wide-angle lens (Figure 1). The camera was pointed vertically downward 1.7 m above the ground. A 1 m^2 frame was central in the photograph, which provided an estimate of scale and allowed us to measure objects and calculate surface areas in the photo. Photographs taken with this camera arrangement were scanned at four resolutions and converted to digital format using a Kodak® PCD 2000 Imaging Workstation (PIW). Pixel sizes of the four resolutions were 0.56 mm^2, 2.25 mm^2, 9 mm^2, or 36 mm^2 ground area. At resolutions of pixel sizes 0.56 mm^2 and 2.25 mm^2 of ground area, we could see squared-off leaf tips which indicates grazing, bird footprints, goose droppings, and weeds. We could also measure wheat cover, and leaf dimensions and color, which can be used to assess wheat vigor. During the second year of the study, platform photographs were scanned using a Nikon® LS-1000 film scanner so that pixels covered 1 mm^2 on the ground.

A ground-level photographic inventory was taken along transect lines that crossed each field at four time intervals during the growing season, corresponding to the timing of aerial overflights. Transect lines were subjectively assigned for each field according to its size and shape to

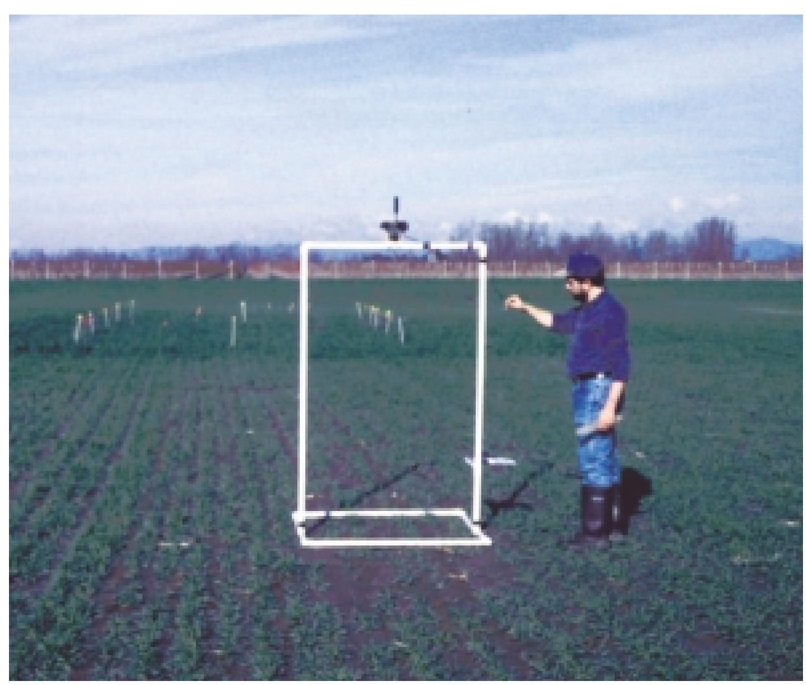

Figure 1 The platform mounted 35 mm camera in the field. A goose exclosure, an area 6 m by 13 m surrounded by poultry fencing, can be seen in the background.

provide broad coverage of portions of the whole field that were grazed by geese, waterlogged, or had thin wheat. Forty to 50 photographs were taken per field during each observation period, spaced at approximately 50 m intervals along transects. Spacing was closer in fields where the technician found high levels of variability or features of interest. At each photographic location we recorded the following information: (1) transect identification number, (2) within transect photo sequence number, (3) relative grazing intensity on a scale of heavy, moderate, light, or none, (4) plant height, (5) any unusual circumstances (flooding, change in soil texture, etc.), and (6) GPS location and time (based on a minimum of 40 positional fixes). A 60 ha field with 60 photo locations required about two hours for two people to sample.

Ground Level Image Analysis

We were interested in determining the cover of wheat and documenting whether grazing by geese had occurred. Cover is defined as the vertical projection of the crown or shoot areas of a plant species on the ground surface, expressed in percent or fraction of the area measured (Stoddart *et al.*, 1975). We measured wheat cover in 1m^2 quadrats at ground level by analyzing digital, color images (Figure 2). We observed that pixels in the digital RGB images of plant leaves and stems had higher green digital numbers than red or blue. Soil, rocks, litter, and dead leaves tended to have lower values for green than for red or blue. This is to be expected since chlorophyll absorbs red (centered about 0.67µm) and blue (centered about 0.45µm) light and reflects green (centered about 0.55µm). We therefore classified images by determining if the average of red and blue digital numbers were greater or less than the green digital number. The digital numbers were ratioed using the following formula:

$$((G-R)+(G-B))/(G+R+G+B)$$

where:

R = digital number of the red channel (0 to 255)
G = digital number of the green channel (0 to 255)
B = digital number of the blue channel (0 to255)

The resultant image had pixel values between -1 and +1 (Figure 3). Negative values tended to be soil/nonliving while positive values were green leaves and stems. In most cases we could threshold with a value near 0 to separate the image into two classes: green leaves and soil/nonliving. Because of changing light and environmental conditions in the field, the threshold did not always lie at zero and we calculated a new threshold. In these cases we calibrated the threshold based on 3-5 platform images per field on each sampling date. We examined the original photograph and the black and white classification side by side on a computer screen and adjusted the threshold until the classification was acceptable. Because fields were sampled in a short time, shifts in solar illumination were minimal. Occasionally the moisture content of the soil surface varied throughout the field and necessitated changing the threshold value. In areas where no grazing had occurred, a threshold value of zero produced the best results, while for intensely grazed

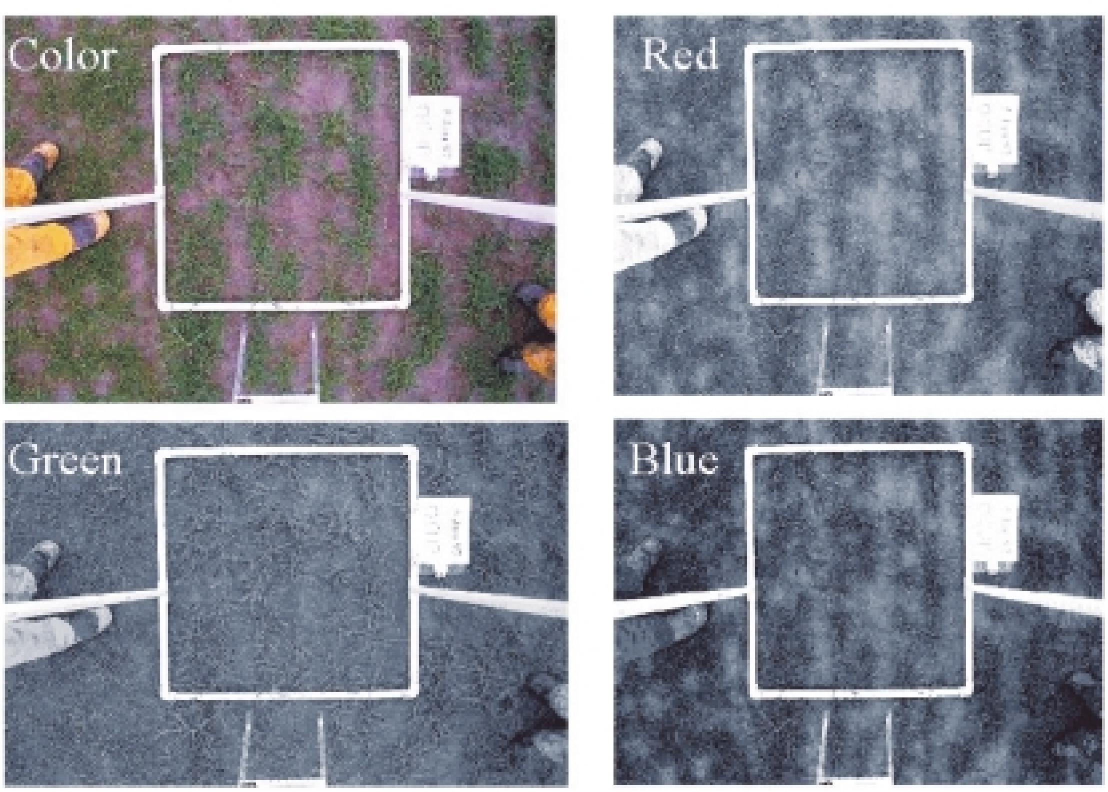

Figure 2 The true color image (top left) was separated into individual components before classification.

areas with very low wheat cover, thresholds ranged from 0.1 to 0.25.

After establishing the threshold, we calculated percentage leaf cover. To evaluate the accuracy of this process, a mask in which black represented either wheat or non-wheat was applied to the original image (Figure 4). Estimates generated from images with pixel sizes of 0.56 mm^2 to 9 mm^2 gave acceptable results. The classification process was programmed in Microsoft® Visual Basic® so classification of 60 photographs can be completed in about 45 minutes. Digital photography, a portable computer, and the program could permit classification in the field and reduce time still further. This leaf cover classification works best when wheat is still short, (i.e. before bolting) which is also when wheat is grazed by geese.

Incorporation of Geographic Information Systems

Our objective was to classify wheat fields into areas that had heavy, moderate, light, or no goose grazing. Aerial images reveal portions of the field with variable wheat cover without revealing the cause. Some areas with sparse wheat are the result of grazing while others may be caused by soil properties, standing water, or farming practices. We combined information in aerial photographs with platform photography and ground-truth data within a GIS to classify the fields. Figure 5 summarizes the three main steps of our methodology. In step 1, we scanned, rectified, and saved color aerial photography for each field. This allowed us to overlay transect data points on the color aerial image since both themes were georeferenced. In step 2, we classified the color aerial image using an unsupervised classification routine. This separated the field into units with similar coverage of wheat (usually two to four classes) and other differences such as trees and roads. In step 3, we assigned causality to each area of thin wheat by verifying with ground-collected information. Platform photography could be reexamined to verify grazed leaf tips, goose droppings, goose footprints, or the presence of other factors. We were able to find areas of the field impacted by soil, standing water, and other animals. Separation of water or soil induced problems from grazing impacts, on the basis of ground-level photos, increased the usefulness of the aerial images. We could also use the platform images to estimate wheat cover across each field and to complete an accuracy assessment.

Each overflight revealed a different pattern of goose use throughout the fields. In December and January when wheat plants were small, geese grazed over most of a field. Only areas near roads or homes, areas close to trees, brush, or tall weeds that could harbor a predator, and strips under power lines were not grazed. It became apparent that the birds were attracted to standing water and the heaviest use was close to low spots in the fields that retained water after a rain.

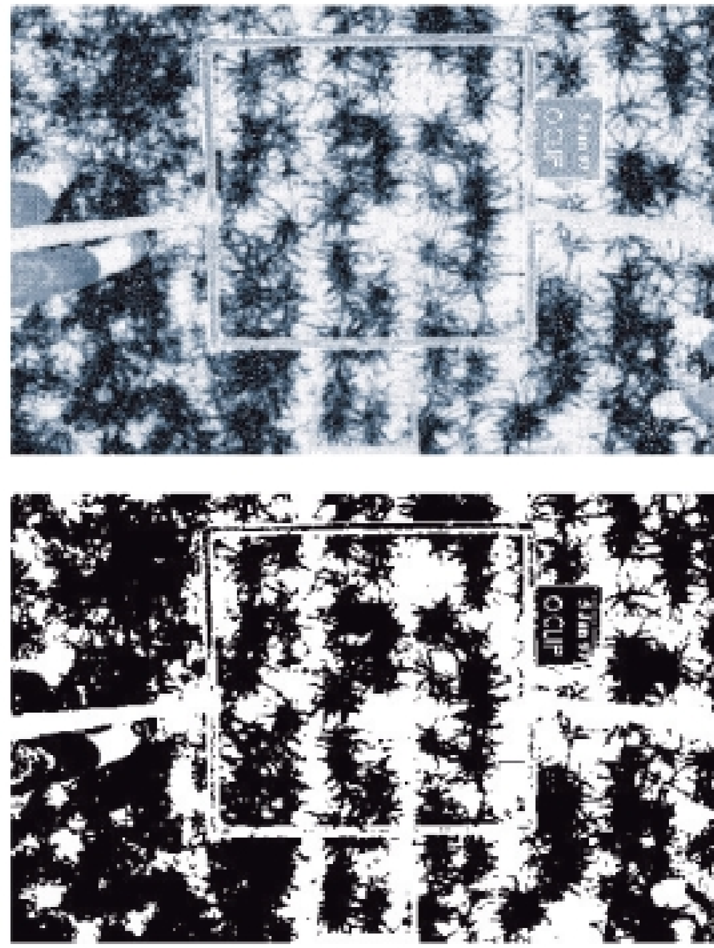

Figure 3 The ratioed image above has values from -1 to +1 which was thresholded to yield the image below. In the lower image, black areas (values greater than 0 in the upper image) represent wheat and white areas (values less than 0 in the upper image) represent soil.

As the season progressed the wheat grew taller and the quantity of food per square meter increased. Goose use became more concentrated and the surface area grazed became smaller. Grazing still occurred in areas with open views in all directions and areas near water but use was less uniform within a field.

By April ungrazed wheat was tall enough to act as a visual barrier restricting use still further. The aerial images from the three overflights and ground/platform photography revealed the spatial and temporal dynamics of the grazing process. We could identify portions of a field that were: 1) grazed continuously from December through mid-April, 2) grazed in December and January but not later, 3) grazed in March and April but not earlier, or 4) ungrazed from December through mid-April. Geese typically leave the Willamette Valley in mid-April.

Conclusions

Our research demonstrates how color aerial images of wheat fields, platform photography, ground observation, and GPS technology can be combined to help classify goose grazing on wheat and map its distribution. Ground-platform images with pixel sizes smaller than of 2.25 mm^2 clearly showed grazed tips of leaves, goose droppings, and footprints that helped document and verify the cause of low wheat cover. We believe that this technique holds promise for field-size mapping of grazing impacts and may be applied in a modified format to other crops and to natural vegetation on rangelands.

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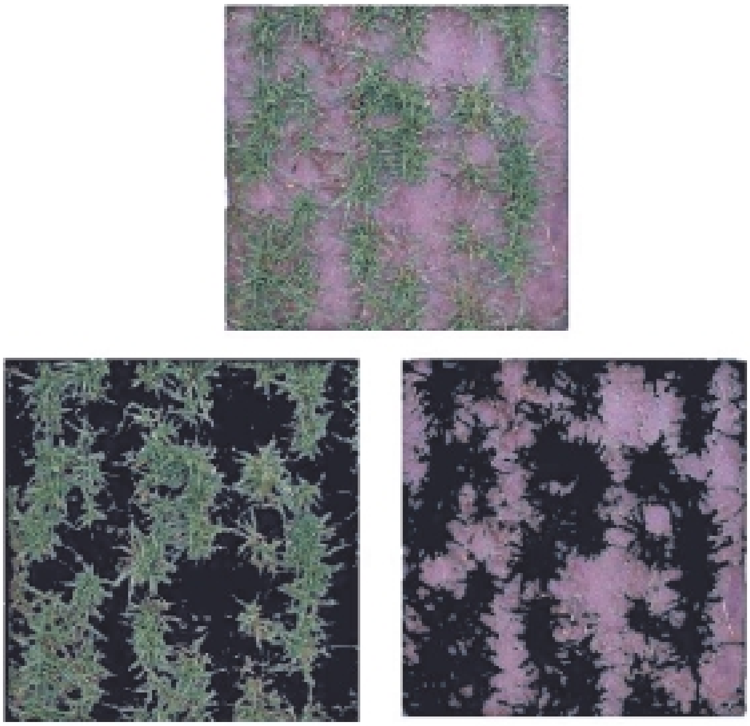

Figure 4 The one square meter photograph (top) scanned at medium resolution (3 mm by 3 mm pixel) has been classified as either wheat or non-wheat. The lower left image has areas classified as wheat shown in true color and non-wheat is shown in black. On the right (the same image window), areas classed as non-wheat are shown in true color and areas classes as wheat are black.

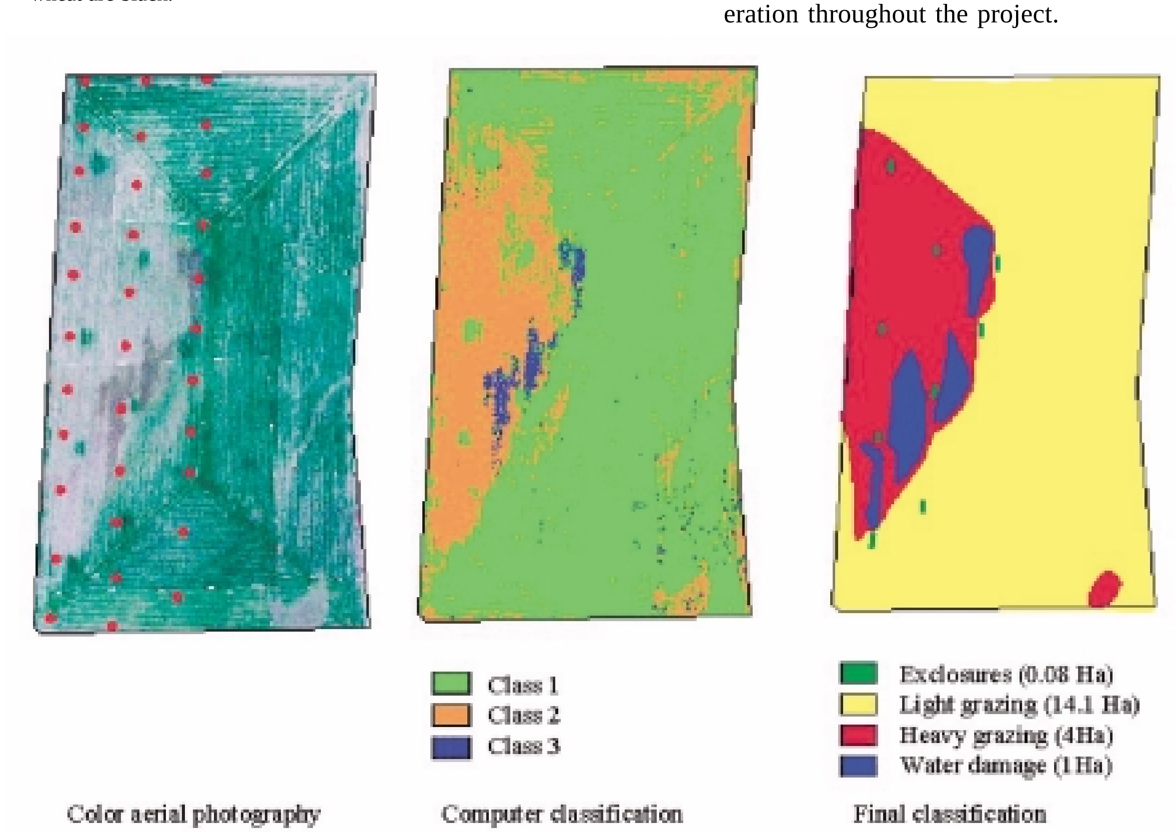

Figure 5 Sources and locations of impact based on January 1998 aerial photography, unsupervised classification, and ground truth verification locations. Ground positions of platform level photographs superimposed as red circles on the aerial photograph. Green rectangles within the field are goose exclosures. Position of the ground photos along transect lines were adjusted in this field to include variability in crop conditions.

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