Site-Specific Management Guidelines

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Selecting the Appropriate Satellite Remote Sensing Product for Precision Farming

Summary

Given the large number of satellite remote sensing products available, it is difficult to select the appropriate one because each satellite has different revisit times, delivery schedules, ordering requirements, pixel resolutions, sensors, and costs. Some satellites collect on a regular schedule (Landsat), while other satellites (IKONOS, QuickBird, and SPOT) need advance programming (tasking). To obtain high resolution satellite information promptly from QuickBird or SPOT, either High Priority or Rush Tasking may need to be purchased. However, high-resolution (small pixel size) data are not needed for all agricultural problems. The purpose of this Guideline is to provide direction on how to select an appropriate satellite-based remote sensing product.

Introduction

To select the most appropriate remote sensing product for an application, it is necessary to understand:

- Basic principles of remote sensing;
- Characteristics of the different information sources;
- The nature of the problem;
- The value of the information.

Remote Sensing Basics

The reflectance value for each pixel is dictated by contributions of all the surfaces within the pixel's coverage and the characteristics of the sensor, namely, the spectral bands. For example, a pixel could contain both bare soil and a growing crop within it. If this pixel encompasses 40% bare soil with a relative reflectance value of 20% and 60% vegetative cover with a relative reflectance value of 60%, then the average reflectance value for the pixel should be about 44% (0.4*20+0.6*60). Pixels containing two or more elements are classified as mixed pixels. A critical component in selecting remote sensing products is matching the pixel resolution to the amount of acceptable mixing. It is important to realize that most pixels, regardless of resolution, are affected by spectral mixing. Pixel mixing can diminish the ability to accurately map boundaries of abnormalities.

In general, the number of surface factors that influence the spectral reflectance tends to increase with increasing pixel size, while the ability to identify these factors tends to decrease. The larger the area covered by a pixel, the greater the likelihood of the pixel containing many different components having different reflectance characteristics. It makes conceptual sense that relatively small pixels are needed for characterizing highly variable areas, while somewhat larger pixels may suffice for characterizing larger scale variability. For example, if only one pixel covered a 40-acre field (1,320 ft. pixel), then all the variability within the field would be represented by one digital value per spectral band. Contrast this situation to a case where 160,000 pixels (3.3 ft. pixel) covered a 40-acre field. Obviously, much more detail within the field can be found in the latter case Additional details about remote sensing is available in Dalsted and Queen (1999), Johannsen et al. (1999), and Schlemmer et al. (1999).

Selecting a Remote Sensing Product

Many land managers ask, "Which satellite remote sensing product is the best?" The answer depends on many factors, including:

- Resolution requirements;
- Turn-around and revisit times;
- Spectral bands measured by the sensor;
- Cost vs. value of the information;
- The possibility of sharing costs with others within the scene;
- Data processing requirements.

Different remote sensing data sources provide different spatial resolutions and spectral band options (**Table 1**). For example, the multispectral data from Modis, Landsat 7 (namely, the Enhanced Thematic Mapper sensor, ETM+), SPOT 2&4, SPOT 5, IKONOS, and QuickBird satellites have pixel sizes of approximately 820, 98, 65, 33, 13, and 8 ft. respectively. Each Landsat 7 pixel is large enough to contain more than 49 IKONOS pixels (**Figure 1**) and in a

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160-acre field there will be greater than 650, 40,000, and 100,000 Landsat TM, IKONOS, and QuickBird pixels, respectively.

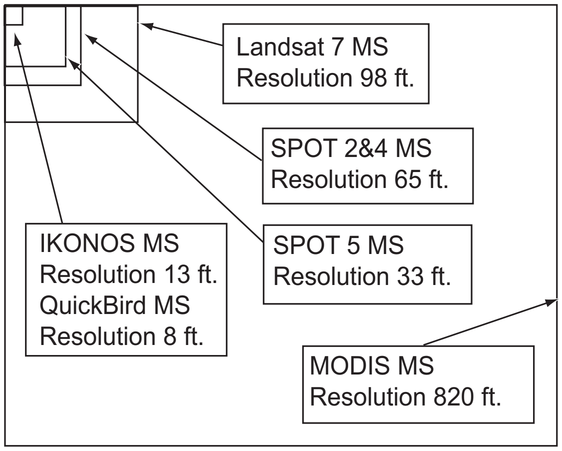

Figure 1. The relative pixel sizes of several different satellite sensors.

Data from the sensors will have different levels of reliability (obtaining ordered data), costs, and turn-around times, i.e., the length of time between collecting the information and delivering it (**Table 1**). The costs and turn-around times shown in **Table 1** were based on a survey of data providers conducted between January and April in 2003. These numbers are constantly changing and it is best to contact the vendor to determine the latest information.

The sensors that provide the spatial resolution most suitable for precision farming (resolution less than 100 ft. and the data can be purchased by private individuals) are Landsat 7, Aster-Terra, SPOT, IKONOS, and QuickBird (**Table 1**). All of these sensors collect at least panchromatic (black and white) and multispectral (green, red, and near infrared) data. Panchromatic images typically have higher resolution (e.g. smaller pixel size) than multispectral images.

The Landsat 7 sensors collect data with a regular 16-day revisit time and therefore a large amount of archived data may be available. This information can be assessed from the EROS Data Center, located near Sioux Falls, South Dakota. Other sensors may not collect data continuously and for these sensors, data may need to be ordered. Ordering data can be relatively expensive (**Table 1**). Satellite tasking is required for SPOT, IKONOS, and QuickBird data (**Table 1**). Tasking allows the imager to concentrate on high priority areas while ignoring areas of low interest. For QuickBird, the period of time to collect non-archived data can be as short as a few days (high priority pricing) up to 60 days. Tasking fees are different for the different satellites. For SPOT, a satellite programming fee of $1,000 is added to each scene ordered.

This fee may be higher for high priority or rush processing. For example, DigitalGlobe offers several priority levels (Standard, Priority, and Rush Tasking) for QuickBird data. For standard tasking, a much lower priority, the customer pays only if the data collected are within minimum specifications, less than 20% clouds, and fair or better image quality in the area of interest.

Table 1. The size of the images, approximate costs (survey conducted January – April, 2003), bands, resolution, turn-around time, and websites for satellite image ordering.

Satellite	Image size	Approximate cost	Band/resolution[1]	Revisit time	Turn-around	Website
	miles	$	ft.	days	days	
Landsat 7[2] (Level 1R)	115 by 106	600 600	Panchromatic/49.2 Multispectral/98.4	16 16	1-3 1-3	http://edc.usgs.gov edc@eos.nasa.gov
ASTER-Terra[3] (Level 1A)	36 by 36	60	Multispectral/49.2	16	6-14	http://edc.usgs.gov http://asterweb.jpl.nasa.gov
MODIS-Terra (MOD09 L2G)	1448 by 1448	free	Panchromatic/ 820	16	6	http://edc.usgs.gov edc@eos.nasa.gov
SPOT 2-5[4] (Level 1A)	37.3 by 37.3	6500+ 3250+ 3250+	Panchromatic/8.2 Panchromatic/16.4 Multispectral/32.8	2	1	http://www.spot.com/ 1-888-749-3201 (Resource 21)
IKONOS 5	6.2 by 6.2	1800 1500	Panchromatic/3.28 Multispectral/13.1	3	2-3	http://www.spaceimaging.com/ 1-800-232-9037
QuickBird[6] (Standard)	10.2 by 10.2	1440 1600	Panchromatic/2 Multispectral/8-9.4	1-4	2-73	http://www.digitalglobe.com 1-800-496-1225

[1] Only information on the highest resolution is provided in the table.

[2] Landsat 7 prices are for radiometric and geo-corrected data.

[3] ASTER images will need to be special ordered because coverage is not continuous. Ordering ASTER images can be difficult.

[4] SPOT images may be delivered faster if a higher priority is purchased. For tasking the satellite a $1,000 programming fee is required; ½, ¼, and ⅛ scenes can also be purchased for reduced costs. Some data processing can be purchased for additional charges.

[5] IKONOS images must be ordered 60 days in advance.

[6] QuickBird images have a normal delivery time of 15 days. For a fee the delivery time can be shortened to 1 day. There is a 10% educational discount for new collections. Several priority levels are available (standard, priority, rush). For high priority the fee is $3,000+20% of the total cost.

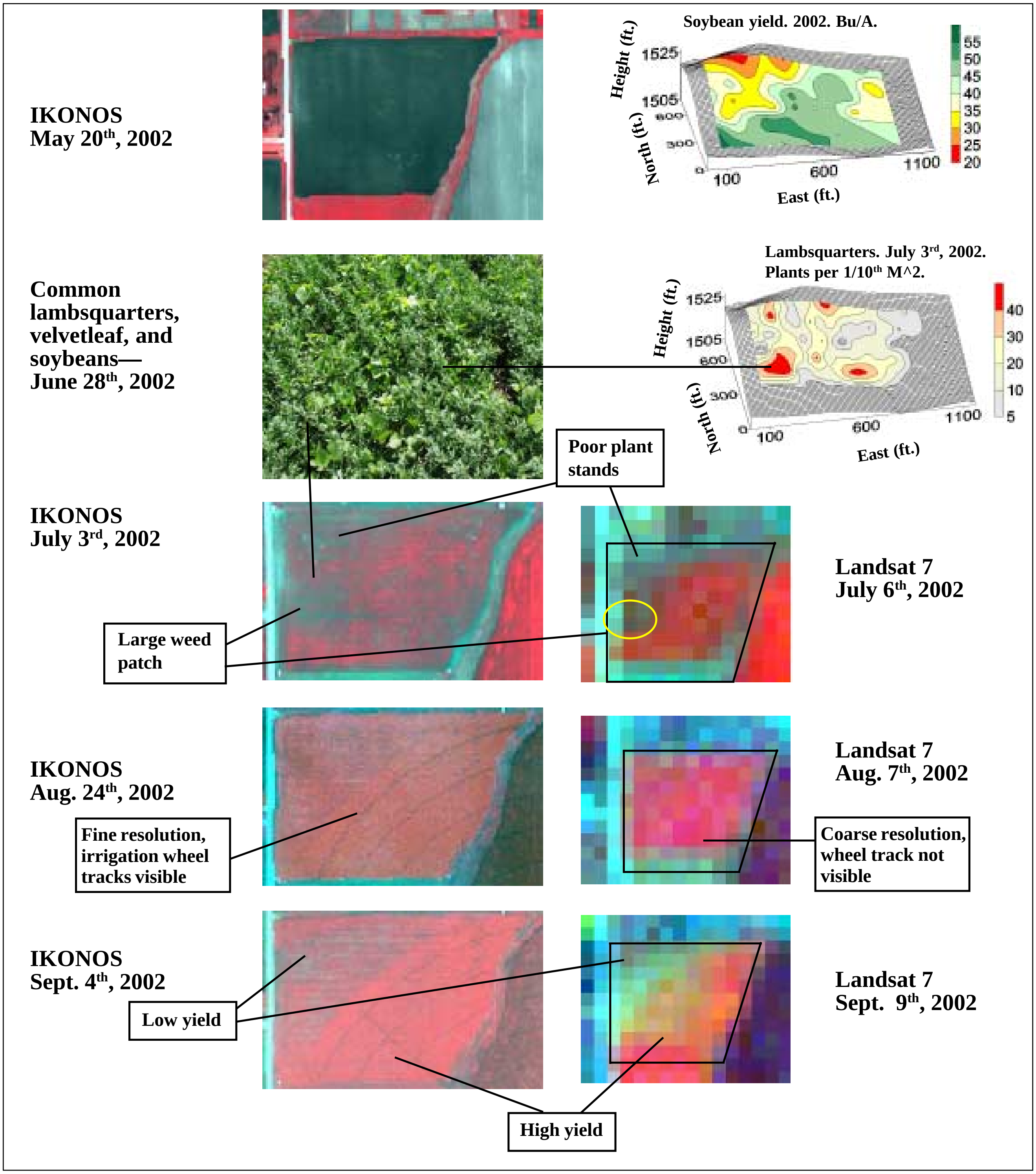

Figure 2. **A comparison of IKONOS and Landsat 7 images collected at different dates from a 20-acre soybean field located in eastern South Dakota. Maps of soybean yield and weed (lambsquarters) are provided for reference purposes.**

DigitalGlobe recommends a 90-day window to collect at the standard priority level, which does not start until five days after the order is confirmed (this period of time is four days for priority tasking). By purchasing priority or rush tasking, the probability that the scene is collected within a narrow time frame is improved. Priority collection involves three collection attempts (with 20% or less clouds) with tasking within four days of the order being placed. The time period for filling an order depends greatly on how many revenue-producing orders exist within reach of the satellite. In some cases the competition is low and collection can be accomplished within a week. Generally, turnaround problems can be “fixed” by paying a high price (cost of a rush delivery). It is important to point out that just because an order is placed on a particular day does not mean it will be delivered. Things such as cloud-cover, satellite trajectory, window size (length of time to deliver the product), off-nadir angle (angle between the satellite and the site), and competition between different customers influence timeliness and the ability of the image provider to deliver the product within the specified time frame.

The highest resolution is not required for all situations. If the goal of remote sensing is to identify large abnormal areas, then the pixel size can be increased with the size of the abnormality. If the producers are using the remote sensing data to direct ground scouting, then sufficient resolution to identify land features may be needed. Keep in mind that small pixels are not always the best selection. Generally, cost and resolution have an inverse relationship. For example, a 115 by 106 mile Landsat scene with a 98 ft. resolution costs $600, while a partial 3.1 by 3.1 mile QuickBird scene with a much higher resolution costs $720 for multispectral and panchromatic data.

Different problems require different resolution and spectral bands and processing approaches. The smaller the extent of a problem, the higher the resolution needed. For example, higher resolution images, such as that obtained from IKONOS or QuickBird, may be needed for locating small weed patches. Larger resolution, such as that obtained from Landsat 7, may be adequate for locating relatively large weed patches, estimating yields, or evaluating hail damage in production fields (**Figure 2**). A more complete description of using remote sensing for assessing weed variability is available in Clay et al. (2003).

Identifying the factor responsible for abnormalities in the multispectral image may be difficult. For example, the areas with the large weed patch and poor plant stand shown in the IKONOS composite image collected on July 3, 2002 looked similar. To separate these factors, ground scouting or additional data processing may be required.

Processing Remote Sensing Data

Data processing may be required to make sense of the data. To process remote sensing data, knowledge and access to geographic information systems (GIS) is helpful, but not required. Landmarks can be used to provide a sense of geographic location. Two of the most commonly used processing techniques are to combine green, red, and near infrared (NIR) band information to develop false color near infrared (green, red, NIR) images, and to calculate a ratio of the red and green spectral bands to form a spectral index such as the normalized difference vegetation index [NDVI= (NIR minus red)/(NIR plus red). These products have been used to assess crop status, health, and identify

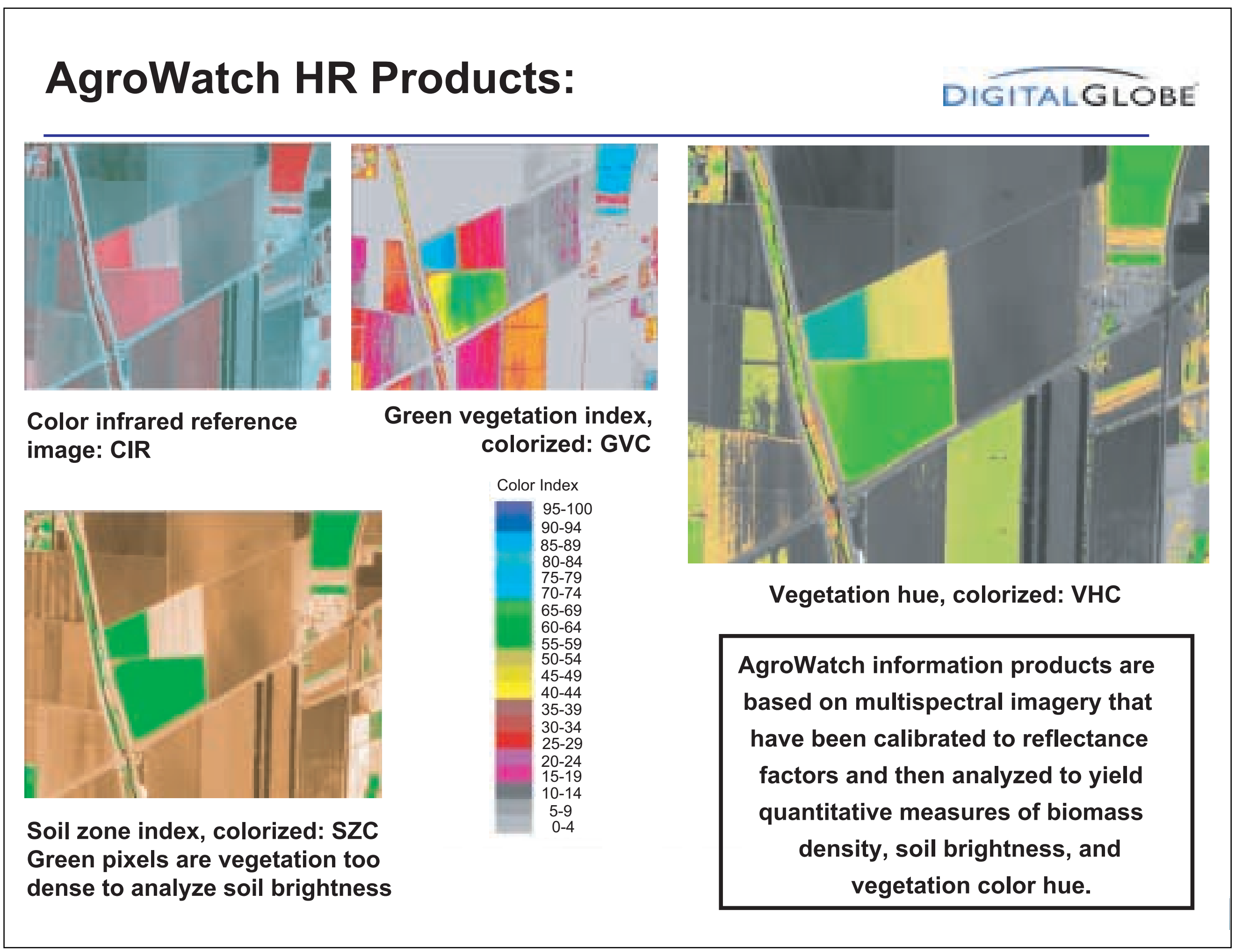

Figure 3. Several different products offered by DigitalGlobe through AgroWatch.

factors limiting yields in production fields. If the user does not have the skills or geographic information systems (GIS) to process remote sensing data, it may be possible to purchase remote sensing in ready-to-use formats.

For example, at selected test markets across the U.S., DigitalGlobe is offering calibrated vegetation biomass, color indices, soil indices, and vegetative change images through its AgroWatch Products (**Figure 3**). Website: > **http://www.digitalglobe.com/products/agro.shtml** <. These products are based on data obtained from SPOT and QuickBird satellites. Similar products, based on digitally enhanced Landsat 7 data resulting in a 49 ft. pixel size, are being offered by Resource21.
Website: > **http://www.resource21.com/default.htm** <. Change maps (relative reflectance at one date subtracted from relative reflectance at a different date) when combined with a basic understand of pest biology can be used to distinguish one problem from another, locate weed patches, diseased areas, and other problems.

Conclusions

We recommend that the following steps be followed prior to selecting a remote sensing product.

- Identify the goals, urgency, and cost vs. budget.
- Determine the resolution and spectral bands needed. Will panchromatic data (i.e., one band across the visible spectrum) suffice or are multispectral data required?
- Determine how the data will be processed. Different data sources have different processing requirements and different companies offer different products.
- Determine the likely value of the imagery. The data should be purchased if the value of the imagery is greater than its cost.

For many end users, obtaining satellite remote sensed imagery may seem daunting. Help is available from a variety of internet sources:

> **http://www.mimas.ac.uk/rs/** <
> **http://www.mapmart.com/** <
> **http://www.ccrs.nrcan.gc.ca/ccrs/** <
> **http://rst.gsfc.nasa.gov/** <
> **http://www.umac.org/** <
> **http://www.esad.ssc.nasa.gov/ag2020/** <
> **http://www.resource21.com/default.htm** <.

If a land manager does not have a lot of experience in selecting and processing remote sensed information, he or she may consider consulting with an expert, purchasing processed products, or joining a learning group or consortium. For example, if land managers are located in South Dakota, North Dakota, Wyoming, Montana, or Idaho they might consider joining the Upper Midwest Aerospace Consortium (UMAC). Website:>**http://www.umac.org/**<. UMAC develops products and services for agriculture, for natural resource management, and for K-12 education, using satellite imagery and other spatial technologies. They also provide information and educational outreach services to the general public with respect to regional impacts of environmental and climatic change. If land managers are located in other states, similar organizations might be available. For more information about these organizations, contact the state's university extension service.

Websites of some of the companies or organizations offering aerial and space-based remote sensing products include:

> **http://www.spaceimaging.com/** <
> **http://landsat7.usgs.gov/index.php** <
> **http://www.spotimage.fr/home/** <
> **http://www.possys.com/** <
> **http://www.airbornedatasystems.com/** <
> **http://www.resource21.com/default.htm** <
> **http://www.agri-vision.net** <
> **http://www.skyhawksensing.com/** <.

The mention of any trade name, products, or websites does not imply endorsement by South Dakota State University, and was provided solely for the convenience of the reader.

It is important to point out that remote sensing can also be obtained from airplane-based systems operated by regional companies. When purchasing these data, similar considerations should be used. ■

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