DESDYNI BIODIVERSITY AND HABITAT KEY VARIABLES AND IMPLICATIONS FOR LIDAR-RADAR FUSION

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1. INTRODUCTION

The National Research Council highlighted remote sensing needs related to biodiversity and habitat in its recent decadal survey [1]. In particular the NRC recommended a mission of combined lidar and InSAR/SAR sensors to measure the variables of “standing biomass, vegetation height and canopy structure, and habitat structure”. Their rationale is well-founded. In terms of habitat, animal species are often considered either “generalists” or “specialists” and many appear to have vegetation 3D structural preferences for their habitat. In terms of biodiversity it is understood that vegetation composition and structure diversity may influence patterns of animal biodiversity and can also influence diversity of other plants (e.g. herbaceous plants under forest canopies). Vegetation 3D structure is very difficult and costly to measure on the ground and radar and lidar have unique capabilities for its measurement [2, 3].

A growing number of studies have begun to investigate use of lidar and radar remote sensing to model habitat or assess biodiversity, and these have recently been reviewed [4, 5]. The majority of lidar studies have used small-footprint lidar although several have employed full-waveform LVIS and most have focused on bird habitat and secondarily on small mammals. Several research designs have used radar-passive optical fusion to create habitat models for birds or quantify diversity patterns for trees. To date none have explicitly fused SAR and lidar for habitat modeling, although one study empirically inter-compared several sensors. Research from both the ecological literature and the remote sensing literature have concurred enough on important variables that these have been identified for the DESDynI mission [5]. This paper assesses these DESDynI lidar-radar mission key variables for biodiversity and habitat specifically in light of implications for lidar-radar fusion.

2. KEY DESDYNI VARIABLES AND CAPABILITIES FOR BIODIVERSITY AND HABITAT

In order for the key variables to meet the DESDynI Level I requirements to be relevant to needs for biodiversity and habitat, for many variables lidar-radar fusion is called for. Key variables include canopy cover, canopy height, canopy height profile, and biomass plus additional variables, and over both pixels/plots and landscapes. Other mission characteristics highlighted as especially important are related to resolutions and orbital and data collection characteristics (Table 1).

Table 1. Key variables and capabilities for biodiversity and habitat suggested for a spaceborne lidar-radar mission plus their implications for lidar-radar fusion.

Variable	Radar	Lidar	Precisions	Fusion
Variables From Single Radar Pixels or Single Lidar Pulses				
Canopy cover (%)	no	yes	10–20% M, 5% D	lidar
HOME (m)	yes	yes	2 m M, 1 m D	radar, lidar, fusion
Maximum canopy height (m)	no	yes	2 m M, 1 m D	lidar, fusion
Canopy height profile	no	yes	1 m, ±5%	lidar
Dry biomass (t/ha)	yes	yes	±20% or 10 tC/ha	lidar, radar, fusion
Basal area	yes	yes		lidar, radar, fusion
Stem density (stems/ha)	no	no	±20%	n/a
Diameter (cm)	no	no	±20%	n/a
Physiognomy	yes	no	(hardwood vs. conifer)	radar
Species	no	no		n/a
Snags (snags/ha)	no	?		n/a
landscape-scale variables				
Canopy cover	?	yes	10–20% M, 5% D	lidar, radar (?)
Canopy texture (stdev height, m)	?	yes	±20% M, ±10% D	lidar, fusion
Height size class distribution	no	yes		lidar
Diameter size class distribution	no	no		n/a
Edge identification/mapping	yes	yes	within pixel/pulse size	lidar, radar, fusion
Landscape pattern	yes	yes	many metrics	lidar, radar, fusion
Surface (ground) roughness (m)	no	yes	±20% M, ±10% D	lidar
other mission capabilities				
Fine spatial resolution data	yes	yes	25 m (lidar), ~30 m radar	lidar, radar, fusion
Local landscapes	yes	no		radar, fusion
Contiguous along-track lidar plots	n/a	yes	30 m spacing along-transect	lidar, fusion
Global coverage	y	y	every 91 days	lidar, radar, fusion
Ability to target disturbance events	y	n		radar

3. DISCUSSION OF IMPLICATIONS FOR LIDAR-RADAR FUSION

In the following discussion we make the assumption that for fusion, lidar will collect data along transects and radar will typically be used to extend the lidar measurements over spatially continuous geographic areas. This discussion also assumes (unless otherwise indicated) that only lidar and radar are to be used for fusion (i.e. rather than field or other sensor data); this is important for assessing needs for DESDynI mission planning.

3.1. Fusion and Key Variables for Biodiversity and Habitat

Canopy Cover: At the pixel level, the biodiversity and habitat key variable Canopy Cover (%) is likely to be only measureable by lidar. At the landscape level, within-lidar plot canopy cover will be measured along transects, whereas for radar Canopy Cover may be mapped between multiple pixels, i.e. where one pixel may have 0% Canopy Cover and another 50% or 100%, however precisions or meaningful data between 0% and 100% have not been evaluated, i.e. the “?” in radar column). In addition this may only be possible through radar-lidar fusion as the radar image data may need to be trained by the lidar data.

Canopy Height Variables: Both radar and lidar retrieve a maximum or median backscatter value somewhere within the canopy. In the case of lidar this is called HOME (height of median energy), and with radar the scattering phase center. Their relationships and thus fusion issues have not been evaluated. The variable Maximum Canopy Height can be directly observed by lidar and observed by radar but measured only with ancillary information (i.e. lidar and physical model). Thus at the plot/pixel level lidar will provide the best measure, and to be extended over landscape lidar-radar fusion is necessary.

Within-Canopy Profile: This variable is expected to be directly retrieved by lidar only and numerous studies have evaluated lidar capabilities. It is not yet know whether fusion with radar will allow extension to areas mapped only by radar. New InSAR (interferometric radar) may be able to retrieve some within canopy profile information [6]; however the method is experimental and precisions are not yet known.

Biomass and Basal Area: Both of these are retrievable from either sensor individually, however for radar the data needs to be calibrated against either a physical model, field data or lidar data. Thus the key methods for these variables will be lidar over transects and lidar-radar fusion over areas.

Physiognomy: When defined as conifer vs. deciduous, this variable is retrievable by radar at both the individual pixel level and over landscapes in cases where patches are relatively homogenous; patches of different forest communities comprised of different multiple species are also distinguished by radar. This variable is unlikely to be a focus of fusion although some emerging studies are attempting to model conifer vs. deciduous canopies using small-footprint lidar.

Canopy Texture: This variable which can give some sense of the complexity of a forest canopy has been estimated by lidar techniques [7], measured as “rugosity”, and texture has also been retrieved by radar. The comparability of the two sensors in terms of “texture measures” and in terms of those meaningful for biodiversity and habitat will need to be evaluated.

Edge Identification/Mapping: Edge identification can only reliably be measured by lidar given contiguous lidar plots along transects; with non-contiguous plots this cannot be reliably estimated. Radar will be able to identify locations of edges over spatially continuous areas and with fusion lidar will be able to provide further information as to the 3D structure of those edges.

Landscape Pattern: There are many landscape pattern metrics and other spatial statistical measures that are well-integrated into biodiversity and habitat mapping and assessment. Lidar will be able to measure some along transects (with contiguous transects providing more data) and radar will be able to measure a variety over spatial areas. While radar will be able to easily identify horizontal patterns, the full 3D characterization of these will be possible through radar-lidar fusion where fusion supplies variables such as spatially varying height or biomass to characterize the vertical or volumetric component of a patch (or other area of landscape).

3.2 Fusion and Other Mission Capabilities for Biodiversity and Habitat

Fine Spatial Resolution Data: Habitat science and management most frequently occurs at local to regional scales and thus this fine nominal spatial resolution data is required for describing habitat and associated biodiversity patterns; both radar and lidar should be collected at fine resolutions for fusion products.

Spatially Explicit over Local Landscapes: Unlike many carbon applications for which statistical sampling may be quite relevant, habitat models and biodiversity assessments are almost always likely to require spatially explicit data, thus accurate and fine-scale lidar-radar fusion is especially important to this application.

Contiguous Along-Track Lidar Plots: Contiguous along-track lidar footprints increase the ability to identify important horizontally-distributed features of forest structure, especially at the fine scale such as treefall gaps and rare landscape features, plus aid in retrieving the ground profile for height retrievals. It follows that contiguous plots should increase the accuracy of fused radar-lidar datasets of key variables over landscapes.

Global Coverage of Forested Ecosystems: Biodiversity and habitat issues vary over the globe. Radar-lidar fusion of key variables and as global datasets is needed.

4. CONCLUSIONS

Key variables for a spaceborne lidar-radar mission have been identified as useful for biodiversity and habitat. A number of these will either require or will benefit from lidar-radar fusion. This paper reviews and interprets those variables in terms of where fusion is needed and identifies a number of cases where approaches to fuse somewhat different measurements from the two sensors will need to be further developed and where further information on precisions is needed.

5. REFERENCES

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