Natural Resources Canada
Canada Center for Remote Sensing

US Geological Survey
EROS Data Center

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Land Cover Database of North America

Summary

Land Cover database of North America for the year 2000 is generated jointly by NRCan-Canada Center for Remote Sensing and US Geological Survey as contribution to the Global Land Cover 2000, project implemented by the Global Vegetation Monitoring Unit, Joint Research Center (JRC) of European Commission

The Land cover– database of North America was compiled using SPOT VEGETATION data from VGT sensor during 2000 growing season at the spatial resolution of 1km. The complete data set, from which this product was compiled, contains two sets of twenty post-seasonally corrected 10-day composites period April – October, one over Canada and the other over US and Center America (from Mexico to Panama).

Considerable effort has been devoted to processing SPOT VEGETATION data, in a way that ensures data consistency for quantitative land surface analysis. The data correction was performed using VGT-Manager, a software system developed at CCRS for SPOT/VGT – S1 and S10 reflectance products enhancement. The information extraction and land cover mapping is carried out with constant consultations between CCRS and USGS scientists. The map will be released as a regional land cover product with 35 land cover classes based on modified Natural Vegetation Classification Standard (NVCS) adopted by US Federal Geographic Data Committee. In addition, a conversion of NVCS to LCCS, officially accepted classification system by GLC 2000, is also provided.

The suggested citation for this data set is:
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1. Summary of Parameters

1.1 Geographic Projection:

Georeference Units	:	LONG/LAT	
Projection	:	Geographic (geodetic)	
Datum - Ellipsoid	:	WGS 1984 (Global Definition) - WGS 84	
Upper Left Corner	:	$179^0$59'56.40" w Lon	$85^0$00'00.00" N Lat
Upper Right Corner	:	$13^0$00'00.00" W Lon	$85^0$00'00.00" N Lat
Image Centre	:	$96^0$29'58.20" W Lon	$42^0$29'53.25" N Lat
Lower Left Corner	:	$179^0$59'56.40" W Lon	$0^0$00'13.51" S Lat
Lower Right Corner	:	$13^0$00'00.00" W Lon	$0^0$00'13.51" S Lat
Pixel Size (in Degrees)	:	0.00893^0 Lon	0.00893^0 Lat
(Equivalent Deg,Min,Sec)	:	$0^0$00'32.14"	$0^0$00'32.14"

1.2 Scaling coefficients (16 to 8 bit)

Channel	Orig. limits/(16 bits)	Reflectance range	New limits/(8 bits)
1 (RED band)	0 - 750	0.0 - 0.375	0 - 255
2 (NIR band)	0 - 1300	0.0 - 0.650	0 - 255
3 (SWIR band)	0 - 1300	0.0 - 0.650	0 - 255

1.3 Usage Guidance

North America 2000 data are available in tiff format. The image is compressed using WinZip and provided as a compressed file.

1.4 Classification Scheme based on modified NVCS-FGDC

Vegetated/Non-vegetated	Life Form	Climate	Leaf Type	Leaf Phenology	Canopy Cover	Land Cover	NVCS_FGDC_CODE
Vegetated Areas							
	Tree Dominated						

Tropical or Sub-tropical					
	Broadleaved				
		Evergreen (>75%)			
			Closed (>60%)	Tropical or Sub-tropical Broadleaved Evergreen Forest - Closed Canopy	1
			Open (25-60%)	Tropical or Sub-tropical Broadleaved Evergreen Forest - Open Canopy	2
		Deciduous (>75%)			
			Closed	Tropical or Sub-tropical Broadleaved Deciduous Forest - Closed Canopy	3
			Open	Tropical or Sub-tropical Broadleaved Deciduous Forest - Open Canopy	4
		Mixed (25 to 75%)			
			Closed	Tropical or Sub-tropical Broadleaved Mixed Forest - Closed Canopy	5
			Open	Tropical or Sub-tropical Broadleaved Mixed Forest - Open Canopy	6
	Needleleaved				
		Evergreen			
			Closed (>60%)	Tropical or Sub-tropical Needleleaved Evergreen Forest - Closed Canopy	7
			Open (25-60%)	Tropical or Sub-tropical Needleleaved Evergreen Forest - Open Canopy	8
		Deciduous			
			Closed	Tropical or Sub-tropical Needleleaved Deciduous Forest - Closed Canopy	9
			Open	Tropical or Sub-tropical Needleleaved Deciduous Forest - Open Canopy	10
		Mixed			
			Closed	Tropical or Sub-tropical Needleleaved Mixed Forest - Closed Canopy	11
			Open	Tropical or Sub-tropical Needleleaved Mixed Forest - Open Canopy	12
	Mixed (mixed phenology or leaf type)				
			Closed	Tropical or Sub-tropical Mixed Broadleaved or Needleleaved Forest - Closed Canopy	13
			Open	Tropical or Sub-tropical Mixed Broadleaved or Needleleaved Forest - Open Canopy	14
Temperate or Sub-polar					
	Broadleaved				
		Evergreen (>75%)			
			Closed (>60%)	Temperate or Sub-polar Broadleaved Evergreen Forest - Closed Canopy	15
			Open (25-60%)	Temperate or Sub-polar Broadleaved Evergreen Forest - Open Canopy	16
		Deciduous (>75%)			
			Closed	Temperate or Sub-polar Broadleaved Deciduous Forest - Closed Canopy	17
			Open	Temperate or Sub-polar Broadleaved Deciduous Forest - Open Canopy	18

			Mixed (25 to 75%)			
				Closed	Temperate or Sub-polar Broadleaved Mixed Forest - Closed Canopy	19
				Open	Temperate or Sub-polar Broadleaved Mixed Forest - Open Canopy	20
		Needleleaved				
			Evergreen			
				Closed (>60%)	Temperate or Sub-polar Needleleaved Evergreen Forest - Closed Canopy	21
				Open (25-60%)	Temperate or Sub-polar Needleleaved Evergreen Forest - Open Canopy	22
			Deciduous	Closed	Temperate or Sub-polar Needleleaved Deciduous Forest - Closed Canopy	23
				Open	Temperate or Sub-polar Needleleaved Deciduous Forest - Open Canopy	24
			Mixed			
				Closed	Temperate or Sub-polar Needleleaved Mixed Forest - Closed Canopy	25
				Open	Temperate or Sub-polar Needleleaved Mixed Forest - Open Canopy	26
		Mixed (mixed phenology or leaf type)				
				Closed	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Closed Canopy	27
				Open	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Open Canopy	28
Shrub Dominated	Shrubland					
(shrubland or scrub - shrub generally greater than 0.5 m tall with individuals or clumps not tourching to) overlapping - generally forming >25% canopy, tree cover generally less than 25%	Tropical or Sub-tropical	Broadleaved				
			Evergreen (>75%)			
				Closed (>60%)	Tropical or Sub-tropical Broadleaved Evergreen Shrubland - Closed Canopy	29
				Open (25-60%)	Tropical or Sub-tropical Broadleaved Evergreen Shrubland - Open Canopy	30
			Deciduous (>75%)			
				Closed	Tropical or Sub-tropical Broadleaved Deciduous Shrubland - Closed Canopy	31
				Open	Tropical or Sub-tropical Broadleaved Deciduous Shrubland - Open Canopy	32
			Mixed (25 to 75%)			
				Closed	Tropical or Sub-tropical Broadleaved Mixed Shrubland - Closed Canopy	33
				Open	Tropical or Sub-tropical Broadleaved Mixed Shrubland - Open Canopy	34
		Needleleaved				
			Evergreen			
				Closed (>60%)	Tropical or Sub-tropical Needleleaved Evergreen Shrubland - Closed Canopy	35
				Open (25-60%)	Tropical or Sub-tropical Needleleaved Evergreen Shrubland - Open Canopy	36
			Deciduous			
				Closed	Tropical or Sub-tropical Needleleaved Deciduous Shrubland - Closed Canopy	37
				Open	Tropical or Sub-tropical Needleleaved Deciduous Shrubland - Open Canopy	38

			Mixed			
				Closed	Tropical or Sub-tropical Needleleaved Mixed Shrubland - Closed Canopy	39
				Open	Tropical or Sub-tropical Needleleaved Mixed Shrubland - Open Canopy	40
		Mixed (mixed phenology or leaf type)				
				Closed	Tropical or Sub-tropical Mixed Broadleaved or Needleleaved Shrubland - Closed Canopy	41
				Open	Tropical or Sub-tropical Mixed Broadleaved or Needleleaved Shrubland - Open Canopy	42
	Temperate or Subpolar					
		Broadleaved				
			Evergreen (>75%)			
				Closed (>60%)	Temperate or Subpolar Broadleaved Evergreen Shrubland - Closed Canopy	43
				Open (25-60%)	Temperate or Subpolar Broadleaved Evergreen Shrubland - Open Canopy	44
			Deciduous (>75%)			
				Closed	Temperate or Subpolar Broadleaved Deciduous Shrubland - Closed Canopy	45
				Open	Temperate or Subpolar Broadleaved Deciduous Shrubland - Open Canopy	46
			Mixed (25 to 75%)			
				Closed	Temperate or Subpolar Broadleaved Mixed Shrubland - Closed Canopy	47
				Open	Temperate or Subpolar Broadleaved Mixed Shrubland - Open Canopy	48
		Needleleaved				
			Evergreen			
				Closed (>60%)	Temperate or Subpolar Needleleaved Evergreen Shrubland - Closed Canopy	49
				Open (25-60%)	Temperate or Subpolar Needleleaved Evergreen Shrubland - Open Canopy	50
			Deciduous	Closed	Temperate or Subpolar Needleleaved Deciduous Shrubland - Closed Canopy	51
				Open	Temperate or Subpolar Needleleaved Deciduous Shrubland - Open Canopy	52
			Mixed			
				Closed	Temperate or Subpolar Needleleaved Mixed Shrubland - Closed Canopy	53
				Open	Temperate or Subpolar Needleleaved Mixed Shrubland - Open Canopy	54
		Mixed (mixed phenology or leaf type)				
				Closed	Temperate or Subpolar Mixed Broadleaved and Needleleaved Shrubland - Closed Canopy	55
				Open	Temperate or Subpolar Mixed Broadleaved and Needleleaved Shrubland - Open Canopy	56
Shrub Dominated (low growing shrub usually under 0.5 m tall, individuals or clumps not touching to overlapping - dwarf-shrubs generally	Dwarf-Shrubland					
	Tropical or Sub-tropical	Broadleaved				
			Evergreen (>75%)			

forming >25% cover - trees and shrubs generally less than 25% cover)				Closed (>60%)	Tropical or Sub-tropical Broadleaved Evergreen Dwarf-Shrubland - Closed Canopy	57
				Open (25-60%)	Tropical or Sub-tropical Broadleaved Evergreen Dwarf-Shrubland - Open Canopy	58
			Deciduous (>75%)			
				Closed	Tropical or Sub-tropical Broadleaved Deciduous Dwarf-Shrubland - Closed Canopy	59
				Open	Tropical or Sub-tropical Broadleaved Deciduous Dwarf-Shrubland - Open Canopy	60
			Mixed (25 to 75%)			
				Closed	Tropical or Sub-tropical Broadleaved Mixed Dwarf-Shrubland - Closed Canopy	61
				Open	Tropical or Sub-tropical Broadleaved Mixed Dwarf-Shrubland - Open Canopy	62
		Needleleaved				
			Evergreen			
				Closed (>60%)	Tropical or Sub-tropical Needleleaved Evergreen Dwarf-Shrubland - Closed Canopy	63
				Open (25-60%)	Tropical or Sub-tropical Needleleaved Evergreen Dwarf-Shrubland - Open Canopy	64
			Deciduous			
				Closed	Tropical or Sub-tropical Needleleaved Deciduous Dwarf-Shrubland - Closed Canopy	65
				Open	Tropical or Sub-tropical Needleleaved Deciduous Dwarf-Shrubland - Open Canopy	66
			Mixed			
				Closed	Tropical or Sub-tropical Needleleaved Mixed Dwarf-Shrubland - Closed Canopy	67
				Open	Tropical or Sub-tropical Needleleaved Mixed Dwarf-Shrubland - Open Canopy	68
		Mixed (mixed phenology or leaf type)				
				Closed	Tropical or Sub-tropical Mixed Broadleaved and Needleleaved Dwarf-Shrubland - Closed Canopy	69
				Open	Tropical or Sub-tropical Mixed Broadleaved and Needleleaved Dwarf-Shrubland - Open Canopy	70
	Temperate or Sub-polar					
		Broadleaved				
			Evergreen (>75%)			
				Closed (>60%)	Temperate or Sub-polar Broadleaved Evergreen Dwarf-Shrubland - Closed Canopy	71
				Open (25-60%)	Temperate or Sub-polar Broadleaved Evergreen Dwarf-Shrubland - Open Canopy	72
			Deciduous (>75%)			
				Closed	Temperate or Sub-polar Broadleaved Deciduous Dwarf-Shrubland - Closed Canopy	73
				Open	Temperate or Sub-polar Broadleaved Deciduous Dwarf-Shrubland - Open Canopy	74
			Mixed (25 to 75%)			
				Closed	Temperate or Sub-polar Broadleaved Mixed Dwarf-Shrubland - Closed Canopy	75
				Open	Temperate or Sub-polar Broadleaved Mixed Dwarf-Shrubland - Open Canopy	76
		Needleleaved				

			Evergreen			
				Closed (>60%)	Temperate or Sub-polar Needleleaved Evergreen Dwarf-Shrubland - Closed Canopy	77
				Open (25-60%)	Temperate or Sub-polar Needleleaved Evergreen Dwarf-Shrubland - Open Canopy	78
			Deciduous	Closed	Temperate or Sub-polar Needleleaved Deciduous Dwarf-Shrubland - Closed Canopy	79
				Open	Temperate or Sub-polar Needleleaved Deciduous Dwarf-Shrubland - Open Canopy	80
			Mixed			
				Closed	Temperate or Sub-polar Needleleaved Mixed Dwarf-Shrubland - Closed Canopy	81
				Open	Temperate or Sub-polar Needleleaved Mixed Dwarf-Shrubland - Open Canopy	82
		Mixed (mixed phenology or leaf type)		Closed	Temperate or Sub-polar Mixed Needleleaved and Needleleaved Dwarf-Shrubland - Closed Canopy	83
				Open	Temperate or Sub-polar Mixed Needleleaved and Needleleaved Dwarf-Shrubland - Open Canopy	84
Herb Dominated (herbs-graminoids, ferbs and ferns) dominant (generally r) forming at least 25% canopy cover) trees, shrubs and dwarf-shurbs generally with less than 25% cove perrenial graminoid (grass), forbs) (ferns) and biennials and annual graminoid or forb vegetation	Tropical or Sub-tropical				Tropical or Sub-tropical Grassland	85
					Tropical or Sub-tropical Grassland with a Sparse Tree Layer	86
					Tropical or Sub-tropical Grassland with a Sparse Shrub Layer	87
					Tropical or Sub-tropical Grassland with a Dwarf-Sparse Shrub Layer	88
	Temperate or Subpolar				Temperate or Subpolar Grassland	89
					Temperate or Subpolar Grassland with a Sparse Tree Layer	90
					Temperate or Subpolar Grassland with a Sparse Shrub Layer	91
					Temperate or Subpolar Grassland with a Dwarf-Sparse Shrub Layer	92
	Polar				Polar Grassland	93
					Polar Grassland with a Sparse Tree Layer	94
					Polar Grassland with a Sparse Shrub Layer	95
					Polar Grassland with a Dwarf-Sparse Shrub Layer	96
					Cropland	97
					Cropland and Tree Cover	98
					Cropland and Shrubland/woodland	99
Nonvascular Dominated (Nonvascular cover (bryophytes, lichens and algae) dominant generally forming at least 25% cover, trees, shrubs, dwarf-shurbs and bers generally lesst than 25% cover)	Lichens and Mosses				Lichens and Mosses	100
					Consolidated Rock Sparse Vegetation	101
					Boulder, Gravel, Cobble, or Talus Sparse Vegetation	102

		Unconsolidated Material Sparse Vegetation	103
Non-Vegetated (<1%)	Vegetation Not Dominant (sparse vegetation 1-10%)		
		Urban and Built-up	104
		Water bodies	105
		Mixes of Water and Land	106
		Snow and Ice	107
Other Classes			
		Flooded Forest	108
		Wetlands	109
		Herbaceous Wetlands	110

Legend conversion lookup table between LCCS and NVCS-FGDC

LCCS Code	LCCS Level	NVCS-FGDC Code	USER_CLASS_NAME
20089-O1 / 20089-O2	A3A10B2XXD1E1-O1 / A3A10B2XXD1E1-O2	1	Tropical or Sub-tropical Broadleaved Evergreen Forest - Closed Canopy
20090-O1 / 20090-O2	A3A10B2XXD1E2-O1 / A3A10B2XXD1E2-O2	3	Tropical or Sub-tropical Broadleaved Deciduous Forest - Closed Canopy
20090-O5 / 20090-O7	A3A10B2XXD1E2-O5 / A3A10B2XXD1E2-O7	17	Temperate or Sub-polar Broadleaved Deciduous Forest - Closed Canopy
20092-O5 / 20092-O7	A3A10B2XXD2E1-O5 / A3A10B2XXD2E1-O7	21	Temperate or Sub-polar Needleleaved Evergreen Forest - Closed Canopy
20134-1-O5 / 20134-1-O7	A3A11B2XXD2E1-A12-O5 / A3A11B2XXD2E1-A12-O7	22	Temperate or Sub-polar Needleleaved Evergreen Forest - Open Canopy
20135-1-O5 / 20135-1-O7	A3A11B2XXD2E2-A12-O5 / A3A11B2XXD2E2-A12-O7	23	Temperate or Sub-polar Needleleaved Deciduous Forest - Closed Canopy
20135-1-O5 / 20135-1-O7	A3A11B2XXD2E2-A12-O5 / A3A11B2XXD2E2-A12-O7	24	Temperate or Sub-polar Needleleaved Deciduous Forest - Open Canopy
20092-O5 / 20093-O5 / 20093-O7	A3A10B2XXD2E1-O5 / A3A10B2XXD2E2-O5 / A3A10B2XXD2E2-O7	25	Temperate or Sub-polar Needleleaved Mixed Forest - Closed Canopy
20088-O5 / 20088-O7 / 20091-O5	A3A10B2XXD1-O5 / A3A10B2XXD1-O7 / A3A10B2XXD2-O5	27	Temperate or Sub-polar Mixed Broadleaved or Needleleaved Forest - Closed Canopy
20130-1-O5 / 20130-1-O7 / 20133-1-O5	A3A11B2XXD1-A12-O5 / A3A11B2XXD1-A12-O7 / A3A11B2XXD2-A12-O5	28	Temperate or Sub-polar Mixed Broaddleleaved or Needleleaved Forest - Open Canopy
20172-1-O1 / 20172-1-O2 / 20175-1-O1	A4A11B3XXD1-A12-O1 / A4A11B3XXD1-A12-O2 / A4A11B3XXD2-A12-O1	42	Tropical or Sub-tropical Mixed Broadleaved or Needleleaved Shrubland - Open Canopy
20152-O5 / 20152-O7	A4A10B3XXD1E1-O5 / A4A10B3XXD1E1-O7	43	Temperate or Subpolar Broadleaved Evergreen Shrubland - Closed Canopy
20174-1-O5 / 20174-1-O7	A4A11B3XXD1E2-A12-O5 / A4A11B3XXD1E2-A12-O7	46	Temperate or Subpolar Broadleaved Deciduous Shrubland - Open Canopy
20155-O5 / 20155-O7	A4A10B3XXD2E1-O5 / A4A10B3XXD2E1-O7	49	Temperate or Subpolar Needleleaved Evergreen Shrubland - Closed Canopy
20176-1-O5 / 20176-1-O7	A4A11B3XXD2E1-A12-O5 / A4A11B3XXD2E1-A12-O7	50	Temperate or Subpolar Needleleaved Evergreen Shrubland - Open Canopy
20172-2-O5 / 20172-2-O7 / 20175-2-O5	A4A11B3XXD1-A12B10-O5 / A4A11B3XXD1-A12B10-O7 / A4A11B3XXD2-A12B10-O5	84	Temperate or Sub-polar Mixed Broadleaved and Needleleaved Dwarf-Shrubland - Open Canopy
20033-01/20033-02/20052-9032-05	A6A10-01/A6A10-02/A3A-14-A16-05	86	Tropical or Sub-tropical Grassland with a Sparse Tree Layer
20033-05/20033-07	A6A10-05/A6A10-07	89	Temperate or Subpolar Grassland
20033-05/20033-07/20052-9032	A6A10-05/A6A10-07/A3A14-A16	90	Temperate or Subpolar Grassland with a Sparse Tree Layer
20033-05/20033-07/20055-9032	A6A10-05/A6A10-07/A4A14-A16	91	Temperate or Subpolar Grassland with a Sparse Shrub Layer
20033-08/20055-9032	A6A10-08/A4A14-A16	95	Polar Grassland with a Sparse Shrub Layer
20033-08/20056-9033	A6A10-08/A4A14B3-A16B10	96	Polar Grassland with a Dwarf-Sparse Shrub Layer
10025	A3	97	Cropland
10025/20052	A3/A3A14	98	Cropland and Tree Cover
10025/20055	A3/A4A14	99	Cropland and Shrubland/woodland
21436-05/21436-07	A8A10-O5 / A8A10-O7	100	Temperate and Subpolar lichen vegetation
6002/20055	A3/A4A14	101	Consolidated Rock Sparse Vegetation
6004/20055	A2/A4A14	103	Unconsolidated Material Sparse Vegetation
5001	A1	104	Urban and Built-up
8001	A1	105	Water bodies
8001/6004	A1/A2	106	Mixes of Water and Land
8005/8008	A2/A3	107	Snow and Ice
4004	A3A12B2	108	Flooded Forest
40007	A3/A13	109	Wetlands
40019	A2/A13	110	Herbaceous Wetlands

2. Data and pre-processing scheme

SPOT4 VEGETATION S10 data acquired from January to December 2000 was used in the analyses. S10 Data were produced by VITO and distributed by SpotImage. Each ten-day composite with spatial resolution of 1km in Platte Carrée projection contains the following four at-surface apparent reflectance bands: blue (0.43-0.47 μm), red (0.61-0.68 μm), near infrared (0.78-0.89 μm), and mid infrared (1.58-1.75μm). Every composite also includes six pseudo bands: composite time grid (specifies the acquisition time for each pixel), solar azimuth (SA), solar zenith (SZ), view zenith (VZ), and view azimuth (VA) angles. More information on S1 and S10 products is available at http://www.spotimage.fr.

To reduce residual cloud contamination and directional anisotropy a post seasonal data correction was applied on VGT- S10 composites acquired over the growing season from April 11 to October 31. The corrections were performed using VGT Manager, a software package specially developed to manipulate and correct VGT S1 or S10 products. The VGT Manger includes several processing modules which are based on the following methods:

Identification of contaminated pixels. The CECANT procedure [1] identifies pixels in which vegetation or soil signal is obscured by atmospheric or surface effects. The pixel-specific algorithm is based on the high contrast between the albedo of land, especially when fully covered by green vegetation, and clouds or snow/ice; and on the difference between measured and expected NDVI value for given pixel and composite period.

Normalization to a common viewing geometry. The NTAM (Non-linear Temporal Angular Model) bi-directional reflectance model [2] is the basis on which the BRDF normalization module was built. The BRDF module enables the derivation of pixel- specific NTAM coefficients on pixel basis (using VGT S1 product) or on land cover type basis (using VGT S10 products). To normalize data to common viewing geometry (Solar zenith=45°, Satellite zenith=0° and Relative azimuth= 0°) the BRDF model coefficients for each VGT band were derived from a set of a land cover - stratified samples. The IGBP land cover map was used for US and Mexico while Land cover Map of Canada 95 generalized to IGBP classers was used over Canada. Only cloud-free pixels were included in the derivation of the model coefficients. The model was then used to normalize reflectance of clear sky pixels to common viewing geometry.

Temporal interpolation for contaminated pixels. When pixels were contaminated during the beginning and the end of the growing season a polynomial temporal interpolation was used to replace the pixel values, while linear interpolation between adjacent non-contaminated values was used during the growing season.

From corrected data the average values of the corrected composites acquired during the July 1-August 31, 2000 period (peek green). Mean values were computed for red NIR and SWIR bands and then scaled from 16 to 8.

3 Other information related to product

The SPOT4 VEGETATION system (VGT 1) is the result of a co-operation between the European Union, France, Sweden, Belgium and Italy. It aims at ensuring a regional and global continuous monitoring of the continental biosphere and of crops. VGT observes the Earth at a resolution of 1.165 km, quite invariable in the swath width of nearly 2250 km. This gives almost daily access to any point on the earth surface. Taking into account the measurements, which have to be discarded due to cloud coverage or bad atmospheric conditions, this feature maximizes the probability of getting one useful measurement per ten-day periods. These characteristics suit the observation and study of seasonal evolutions in the biosphere and its processes. Moreover, SPOT enables to lead these studies and observations in a multi-scale context, as the spectral bands and geometrical references of the VEGETATION instrument are the same for the two HRVIR instruments, the three instruments being inter-calibrated.

The VEGETATION (VGT) sensor is a four - channel pushbroom imaging radiometer that measures reflected radiation in two visible, one near infrared, and one middle infrared channel. The VGT objectives are to characterize the main features of plant canopies: absorption by chlorophyll, water contents and structural properties. The best and minimal set of spectral bands known to fulfill this need is composed of:
- a red band centred on the absorption peak of the chlorophyll (0.665 micrometres),
- a near infrared band corresponding to the maximum vegetation spectral reflectance and principally related to the structural properties of the canopies and to percentage of soil covered by vegetation, and
- a mid infrared band centred around 1.65 micrometres where reflectance is related to water content of the canopy components and to its structure.

An additional band is provided in order to compute or characterize the atmospheric state (aerosols):
- a blue band (between 0.45 and 0.50 micrometres) where ground reflectance of vegetation cover is minimal and atmospheric aerosol diffusion effects are maximal.

The influence of atmospheric water vapour, which is most important in a wide near infrared band, is substantially decreased by limiting the upper portion of the near infrared band to avoid the 0.935 micrometres water vapour absorption band.

For VGT 1 on-board SPOT4, an additional consideration is the desire for similarity of VGT spectral bands to those of HRVIR, a high resolution sensor located on the same platform <http://spot4.cnes.fr/spot4_fr/satellit.htm>, at least for the 3 spectral bands common to both sensors (red, near infrared, short wave infrared). With those considerations, the VGT spectral characteristics are as follows:

Spectral bands

Channel	Wavelength range (micrometres)
BLUE	0.43 - 0.47
RED	0.61 - 0.68
NIR	0.78 - 0.89
SWIR	1.58 - 1.75

Operation specifications

Equator crossing time: 10:30 local solar time, in descending mode. The VGT is capable of operating in both real-time and recorded modes.All spectral bands at full spatial resolution acquired on terrestrial areas may be stored onboard in a solid state memory, allowing the use of only one receiving station to which data will be transmitted in X-band. All the spectral bands will also be transmitted in L-band, for possible local receiving stations. Telemetry can be sent at a ' global mode' level at 8,153 MHz (X-band), at a rate of 3.4 Megabits per second (Mbps). Over certain regions it can also be transmitted in L-band (1,704 MHz) at a rate of 0.51 Mbps. For this product, the VGT data were downloaded from <http://free.vgt.vito.be>.

Instrument Description

The VEGETATION is an independent instrument, which complements the main SPOT4 payload, HRVIR (High Resolution Visible Infrared). It is a complete and autonomous system made up of the following subsystems :

- an imaging instrument consisting of 4 independent cameras,
- an image processing module for synchronizing transmission rates and formatting,
- an on-board management system for activating and monitoring equipment,
- a recorder storing up to 97 minutes of imagery,
- X-band telemetry for transmitting recorded data,
- L-band telemetry for direct transmission of imagery,
- a control unit and calibration lamp as well as heaters for thermal control.

The instrument design uses 4 cameras, one for each spectral band and covering the entire field of view. Each camera has an array of 1 728 light-sensitive detectors (elementary detectors), identical to those used by SPOT 4 in the visible (the B0, B2 and B3 spectral bands), each measuring 13 x 13 micrometres, and also a line of 10 modules of 300 detectors each for the shortwave infrared, with each elementary detector measuring 20 x 30 micrometres.

Following analogue equalization, the four spectral channels are grouped together and multiplexed by an analogue-to-digital converter (ADC) using 10 bit encoding. The signals are sent to the video electronics package for digitizing. They are then transmitted to the image processing device, which sends them either to the `on-board` recorder or to the telemetry channel.

Platform

The VGT data used were collected on board the SPOT-4 polar orbiting platform.

Mission Objectives

Three types of mission were identified for the system, taking into account the need for measurements of surface characteristics and the existence of other systems which are already or will provide other measurements which to infer various parameters related to biosphere processes (Saint, 1996):

- Surface parameters mapping. This is the basic requirement, especially for climate and meteorological studies where boundary conditions have to be prescribed as in the case of

General Circulation Models or forecasting models. Factors such as albedo, surface roughness, resistances to heat exchanges —sensible and latent— are important variables for these models and they can be either determined directly from the measurements or inferred from identification of land cover.

- Agricultural, pastoral and forest production. The focus is on the management of crop production for agricultural exporting countries, the monitoring of pastoral resources and their dependence from meteorological evolution, the evaluation of possible global impacts of deforestation and more generally on the need for information related to political or social orientations and decisions.

- Terrestrial biosphere monitoring and modeling: the contribution of the continental biosphere to the biogeochemical cycles (exchanges of carbon and other trace gases) and to water and energy exchanges is one of the objectives of the development of global models. Interaction with human activities is also one of the main points to be studied.

Principles of Operation

The VEGETATION is a four-channel pushbroom imaging radiometer, which detects reflected radiation from the Earth in the visible (blue, red), near-infrared and mid infrared regions of the electromagnetic spectrum.

Instrument Measurement Geometry

The nominal resolution for optimizing the instrument mission is defined by pixels of 1.165 x 1.165 km.

The Equator crossing occurs in descending node at 10:30 local solar time.

The processed images have been checked for geometric registration accuracy (Sylvander et al., 2000). For the period prior to March, 1999 the following results were obtained:

Absolute location accuracy: rms = 725 m, maximum (95%) 1380 m.
Multitemporal registration: rms = 885 m, maximum (95%) 1715 m.

Radiometric Resolution

The radiometric resolution (smallest radiance that is detected) is expressed in terms of Noise Equivalent Difference of Reflectance (NEdR) that is detected within reflectances for each spectral bands. The ranges for surface reflectance (allowing for saturation for some land covers as snow or bright soils in some conditions or spectral bands and for clouds) are consistent with usual reflectance values:

Spectral band	Surface reflectance range
BLUE (B0)	0.0 - 0.5
RED (B2)	0.0 - 0.5
NIR (B3)	0.0 - 0.7
SWIR (B4)	0.0 - 0.6

The surface reflectance resolution is of the order of 0.001 to 0.003 with some adjustments for the different bands:

- for the red band, as vegetation ground reflectances are low (generally less than 0.1), the NEdR is of 0.001 for reflectance up to 0.1 for analysis on small blocks of pixels corresponding to areas of about 10x10 km. The value for NEdR increase linearly up to 0.003 for reflectances values of about 0.5;
- for the NIR and SWIR bands, reflectance differences of 0.003 are detectable for the entire range of reflectances and either for small blocks or the entire image;
- for the blue band, as the variation of "Top of the Atmosphere" reflectance for the extreme conditions of atmospheric conditions (from 5 km to 23 km visibility) is about 0.035, differences of about 0.003 are detectable.

Radiometric Calibration

VEGETATION is calibrated through pre-flight measurements (estimated to have accuracy of 8%, Leroy et al., 1990), on-board calibration lamp (with about 100 detectors per camera and scanning the entire field of view one a month), with in situ instruments, over Rayleigh scattering, over sun glint, over deserts, and over clouds. Based on these tests, the estimated calibration accuracy is (Henry and Meygret, 2000):

Absolute calibration: around 5% for visible and near infrared bands
Multidate calibration: better than 2%
Interband calibration: B2/B3: 2% B2/B0 and B2/B1: 3%
HRVIR/VGT calibration: B2: 3% B3 and SWIR: 2%.

Other Calibration Information

The following ranges and values were used with the S10 composite images (Section 9.2).

VGT Channel	Units	Min	Max	Min DSL	Max DSL
1	Reflectance	0	1	0	2000
2	Reflectance	0	1	0	2000
3	Reflectance	0	1	0	2000
4	Reflectance	0	1	0	2000
NDVI	Unitless	-1	1	0	20000
SUN AZIMUTH	Degree	0	360	0	240
SUN ZENITH	Degree	0	90	0	180
VIEW AZIMUTH	Degree	0	360	0	240
VIEW ZENITH	Degree	0	90	0	180

Time Grid HHMN
Reference date: date of the beginning of the first segment
Status Map Radiometric quality
B0 (1 bit - bit number 1 (MSB)) coded as 0 if bad and 1 if good
B2 (1 bit - bit number 2) coded as 0 if bad and 1 if good
B3 (1 bit - bit number 3) coded as 0 if bad and 1 if good

MIR (1 bit - bit number 4) coded as 0 if bad and 1 if good
land or water (1 bit - bit number 5) coded as 0 if sea and 1 if not
ice/snow or not (1 bit - bit number 6) coded as 1 if there is ice/snow, and 0 if not
cloud or not (1 bit - bit number 7) coded as 1 if there is clouds, and 0 if not

Data Acquisition Methods

The SPOT4 VGT satellite data were acquired by the Centre national d'études spatiales (CNES) at Toulouse, France.

Spatial Characteristics.

Data were distributed by CNES as a North American window with upper left corner 180.00W longitude; 75.00N latitude and lower right corner 13.00W longitude; 40.00N latitude. However, only data covering Canadian landmass were processed and used to derive this land cover product. Note that the northern part of Canada was not included in this window (refer to Section 9.2.2.

Spatial Coverage

The VGT field of view has a maximum off-nadir observation angle of about 50.5° (2250 km swath width). Thus globally, about 90% of the equatorial areas are imaged each day, the remaining 10% being imaged the next day. For latitudes higher than 35° (North and South), all regions are acquired at least once a day (see also Section 6.3.1).

Temporal Characteristics

For equatorial areas, there is a gap between consecutive orbits of the same day, while for higher latitudes, there is a large overlap. The equatorial gap is filled the next four days, so that over the entire 26-day cycle, only 5 days do not give any observation. About 90% of the equatorial areas are imaged each day, the remaining 10% being imaged the next day. The number of "missing days" decreases for higher latitudes and at about 32-35 degrees (N or S) every day provides at least one observation.

Temporal Resolution

At northern latitudes (north of 35 degrees), daily coverage (or more frequently due to overlapping swaths) is provided by the VGT. The overall time period of data acquisition for this land cover map was from April 11 through October 31, 1998. These data were used for preparing the initial data set for the land cover product. The actually classified data were taken from the July- August 1998 period (peak green part of the season).

Reference:

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