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Towards a comprehensive vision

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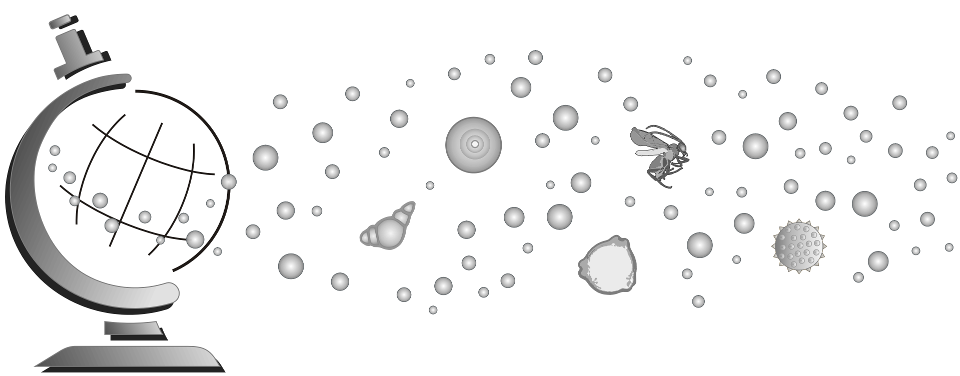

Edited by Bernard Clot, Paul Comtois and Beatriz Escamilla-Garcia

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Contents

Detection of large ragweed populations using remote sensing data.

Yves Auda[1], Chantal Déchamp[2*], Henriette Méon[2, 3], David Duisit[4], Jean-Luc Pontier[4], Solofoarisoa Rakotoniaina[5].

[1]CESBIO, Centre de Télédétection Spatiale, Bpi 2801, 31401 Toulouse, France. [2]AFEDA, 25 Rue Ambroise Paré, 69 800 Saint-Priest, France. [3]Université Lyon1, UMR CNRS PEPS 5125, Bât. Géode, 2 Rue Dubois, 69622 Villeurbanne Cedex France. [4]Service Environnement/Nature, Communauté d'Agglomération du Pays Viennois, 30 Avenue Général Leclerc Espace Saint Germain, Bât. ANTARES, 38209 Vienne Cedex, France. [5]Institut et Observatoire de Géophysique d'Antananarivo, B.P 3843, Université d'Antananarivo, Madagascar.

ABSTRACT

Ragweed, *Ambrosia artemisiifolia* L., is an annual plant producing allergenic pollen. In 2005, about 20% of people living in the Rhône department (France) were affected by ragweed allergy. Six departments of the Rhône-Alpes Region are infested by this plant (Ain, Ardèche, Drôme, Isère, Loire and Rhône). Our goal is to validate a method for a yearly ragweed infestation mapping that could be used for alerting the population.

During 2001–2005, experiments were carried out at the Rhône-Alpes Region. We have established the spectral reflectance of *Ambrosia artemisiifolia* L., which was different from other neighbouring species. Detection using remote sensing showed that large parcels were infested with ragweed.

In 2001 and 2003, ground truth experiments, aim to delineate training sites of pure crop and very infested zones, were realized in small areas around Lyon (Saint-Priest, Rhône department, France). Terra Aster images (from June 23 and from August 13 2001) and Spot 4 image (from July 14 2003) were segregated using maximum likelihood classification. On these small areas, the method worked well: 90 % of pixels were correctly classified.

In 2005, the last experiment was achieved in Estrablin, a village in Isère department, France, which covers a larger area. Up to 30% of cultivated land showed an indication of ragweed infestation. Using a Spot 5 multispectral satellite image acquired on August 16 2005, a maximum likelihood classification was based on classes crossing the type of crop with the infestation importance. The accuracy of the proposed method was demonstrated through the clearness of visual representations.

Key words

Ambrosia artemisiifolia L., common ragweed, France, remote sensing

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*Corresponding author e-mail address: afeda@wanadoo.fr

INTRODUCTION

Common ragweed (*Ambrosia artemisiifolia* L.) is an invasive plant considered as a biological pollutant responsible for severe allergic diseases (Déchamp and Méon, 2003). In 2005, up to 20% of the population living in some sectors of the Rhône department, were affected. By now several approaches have been undertaken in order to better understand the colonization of the French territory by this plant and to try to limit its spreading. Pollen counts, information campaigns and ecological studies have been realized. Nevertheless, no map of ragweed distribution exists for the Rhône-Alpes Region. As terrestrial surveys could not be made on an area of more than 40 000 km^2, only remote sensing methods seem possible. In order to assess the potential of detecting common ragweed from space, we have realized some experiments from 2001 to 2005.

MATERIALS AND METHODS

In order to detect species by using remote sensing, two conditions are required: their spectral signature must be distinct from other plants, and colonized areas must be sufficiently large to be detected from space. These conditions evidently depend on the spatial and spectral resolutions of the sensor. Our contribution aims to clarify these points by developing "ground-based truth" studies at the Rhône-Alpes Region (Fig. 1).

Auda *et al*. (2002, 2008), have determined the spectral reflectance of *Ambrosia artemisiifolia* L. and have compared it to a ten years old not irrigate lawn, composed essentially by Gramineae. This spectral reflectance was particularly different for red wavelength (660 nm) (Fig. 2). Then, optical sensors (Landsat TM, Terra Aster and Spot) which record data in red and near infrared (NIR) bands are adequate to detect common ragweed.

From 2001 to 2003, some experiments were carried out to explore the practicability of satellite detection of short ragweed.

In 2001, ground experiments took place in Saint-Priest around Lyon, Rhône department, (Déchamp and Méon, 2003). On July 27 2001,

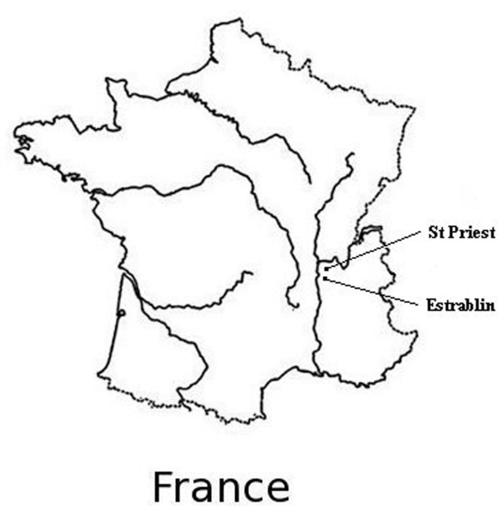

Figure 1. Situation of the studied zones.

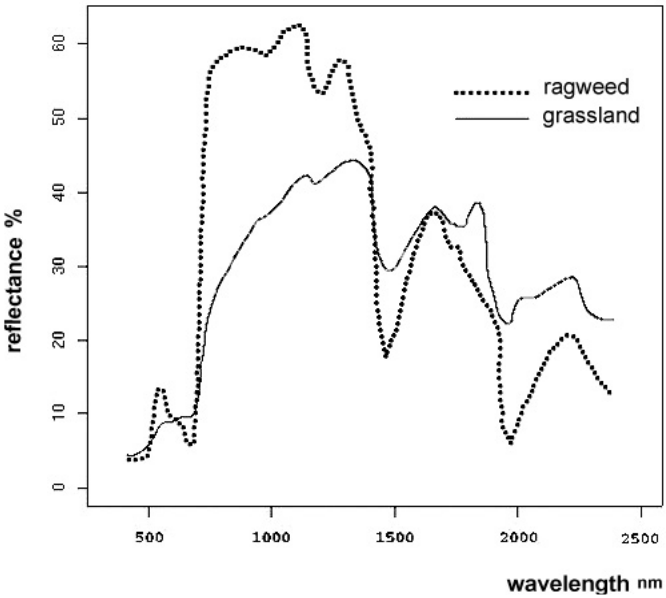

Figure 2. Spectral response of ragweed compared to grassland.

land use was recorded on a small area (2 km²). Zones entirely covered with ragweed could be recorded. Less infested zones showing mixed coverage of cultivated plants and ragweed were not taken into account during the training process.

Five classes were defined: pure ragweed, maize, barred soil, forest, roads and urban area. At the same time, Terra Aster satellite images of June 23 and August 13 2001, were acquired. Each image is composed of 3 bands of different wavelengths: [520 - 600 nm], [630 - 690 nm] and [760 - 860 nm]. Spatial resolution is 15 m/pixel. In order to be superposed, both images were geo-referenced. A maximum likelihood classification was carried out on the two superposed satellite images (Fig. 3A). Permanent landscape patterns like roads and forests were correctly classified. Maize fields were also correctly identified and fields heavily infested with ragweed could be easily distinguished from other neighbouring crops. Nevertheless, the studied zone was too small to allow definitive conclusions about ragweed detection.

In 2003, the survey was extended to an area of 10 km² (Méon *et al.,* 2005). A Spot 4 image, from July 14 2003, showed 4 spectral bands [500 – 590 nm], [610-680 nm], [780 – 890 nm] and [1580 – 1750 nm]. Spatial resolution was 20 m/pixel. A ground survey identified 9 classes: ragweed, forest, maize, sunflower, stubble, water, road, urban area (houses, parking lots), and industry (metallic roofs, cement). Homogeneous patches for these 9 classes were delimited in order to carry out a supervised classification. The quality of classification (90% of pixels correctly classified) and exactness of infestation sites were confirmed by a new extended qualitative ground survey. Some confusion observed between road, urban zone and industry was expected because these classes often intermingled.

Some training zones included other categories and ragweed mingled. A small part of training zones, classified as stubble or industry, were infested with ragweed.

Figure 3B illustrates classification results. Ragweed infested area covers 4% of the studied zone (1.4 km^2). If this calculation was extended to the whole satellite image, 2% of the area would be infested (89 km^2). No further ground truth was realized outside the small studied zone and this last statistic had to be confirmed by new experiments on the whole area covered by the satellite image.

The exceptional dryness of 2003 summer made detection of ragweed easier. Ground observations showed that, ragweed keeps green leaves even under hydric stress, while other species turn yellow.

In 2005, an experiment was carried in Estrablin (Isère department, France). At the end of July, land use and importance of ragweed infestation were precisely sampled on 30% (3.65 km^2) of the surface of the village (Auda *et al.,* 2008). For each parcel, data recorded were:

a. Type of cultivated plants: wheat, maize, sunflower, colza, fallow lands, others;

b. Infestation importance: none, low (<5 plants/m^2), moderate (from 5 to 20 plants/m^2), high (>20 plants/m^2).

The importance of the infestation was registered by an observer who walked around each parcel. Whatever the crop was reaped or not was also registered.

A Spot 5 image acquired on August 16 2005, showed 4 spectral bands [500 - 590 nm], [610 - 680 nm], [780 - 890 nm], [1580 – 1750 nm]. Spatial resolution was 20 m/pixel for the mid infrared canal (MIR) and 10 m/pixel for the others.

Using Geographic Information System facilities (GIS), the ground collected data and the satellite image were analysed and compared. Parcel data were linked to the BDTopo land registry (IGN 2008a). The satellite image was geo-referenced by the Lambert 2 projection system (IGN 2008b). Each satellite pixel inside the parcels was associated to an infestation category and to a type of crop.

To detect ragweed, a maximum likelihood supervised classification was prepared. Classes were built by crossing crop and infestation importance. Pixels were distributed at random into two groups of equal size. The first group was used as a training sample. The second group was used as a test sample. Error matrix was computed from the test sample.

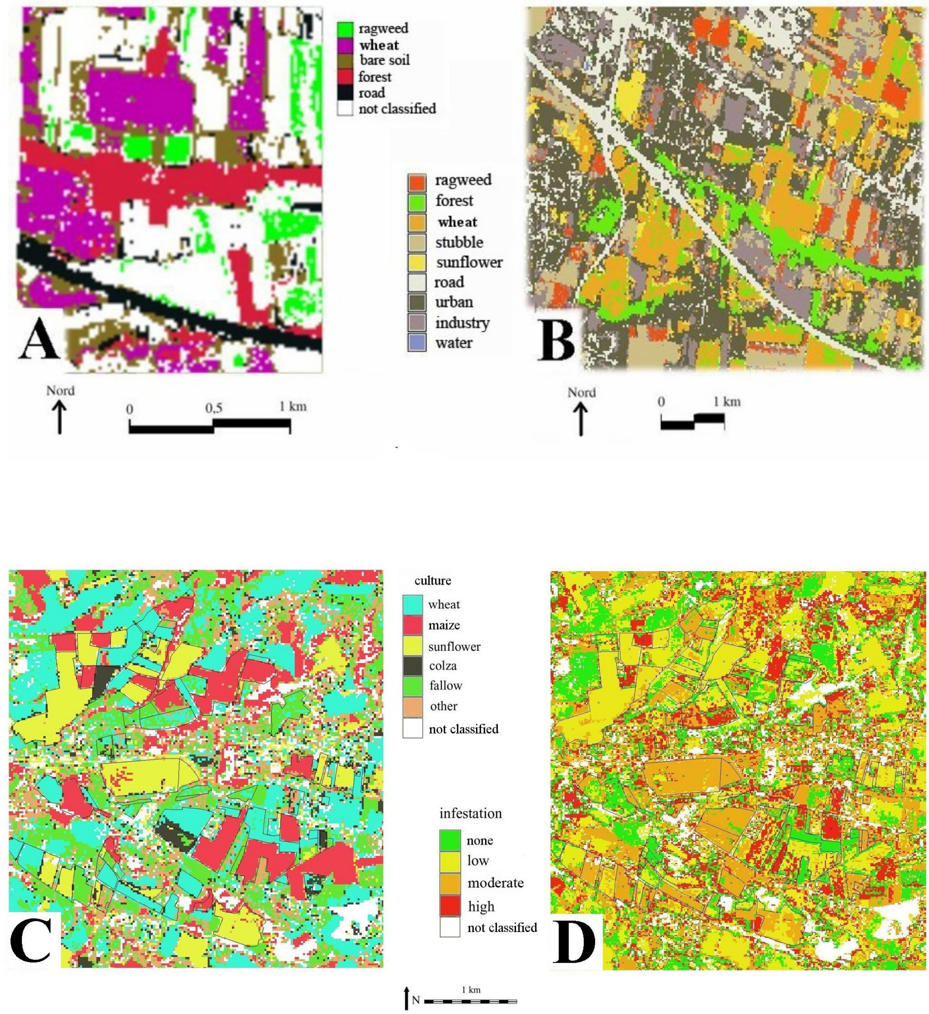

Figure 3. Supervised maximum likelihood classification using (A) Terra Aster images (June 23 and August 13 2001). (B) Spot 4 image (July 14 2003) and Spot 5 image (August 16 2005). (C) Culture map: 80% of pixels are correctly classified considering the culture factor. (D) Infestation map: percentage of pixels classified as infested and really infested is 80%.

RESULTS

Following results refer only to experiments realized in Estrablin in 2005. Statistics obtained from a geospatial database are shown in table 1. They confirm agricultural practice. At the end of July, colza fields were reaped. Neither sunflower nor maize was cropped. They also showed that 93% of areas were infested. But, as every sunflower field and every colza field were infested, it was not possible to determine the pure spectral signature of these cultures.

Table 1. Infestation according to culture computed from field survey data in Estrablin village (Isère department, France, 2005).

	Infestation importance			
Culture	None	Low	Moderate	High
Wheat	5.60	7.72	6.12	9.09
Maize	0.52	12.04	14.41	1.31
Sunflower	0	15.06	19.57	0
Colza	0	1.77	2.51	0
Fallow land	0.30	0.18	1.44	0.64
Others	0.32	0	0.71	0.69
% total	7	37	45	12

Classes crossing cultures and infestation importance were also built. Table 2 shows results of classes used to classify the satellite images. Numbers included all data; training sample and tested zone were merged.

Table 2. Classes used in supervised maximum likelihood classification. Numbers of pixels correspond to parcels identified during ground truth in 2005.

Culture x Infestation	**Number of pixels**
Wheat x None	2046
Maize x None	191
Fallow land x None	109
Others x None	116
Wheat x Low	2817
Maize x Low	4394
Sunflower x Low	5498
Colza x Low	645
Fallow land x Low	64
Wheat x Moderate	2233
Maize x Moderate	5261
Sunflower x Moderate	7144
Colza x Moderate	918
Fallow land x Moderate	527
Others x Moderate	260
Wheat x High	3318
Maize x High	478
Fallow land x High	234
Others x High	251

To facilitate the identification of crops in each parcel and to estimate their level of ragweed infestation, Error matrix (Table 3) was used to analyse classification results.

Percentages of crops correctly classified were high. For maize, colza and sunflower, values were greater than 80%. By contrast, results for wheat were lower (67%). This lower value can be explained by the confusion between harvested wheat field and fallow land, since an infested harvested wheat field which is covered by a dense green population of ragweed has the same ground cover as a fallow land.

In terms of percentages of infestation importance, correctly classified pixels were relatively low (45%). When each culture was examined separately, statistics were better. Inside fallow land, percentage of correctly classified pixels was greater than 70% for all categories of infestation importance.

As previously mentioned, moderate quality results for wheat are due to confusion with fallow land. No conclusion could be definitive for sunflower and colza because every field was infested. When the category of infestation importance was grouped to separate non-infested areas from infested areas, percentage of correctly classified pixels was very high (81%).

To facilitate visual interpretation of classification, classes were grouped to separately map infestation and crops. On the crops map of figure 3C, good delineation of parcels confirms the quality of the method. Therefore, comparison of figures 3C and 3D shows that parcels are quite homogeneous for crops and more heterogeneous for infestation importance. These results are in agreement with ground observations. Each parcel could have more or less infested spatial areas whereas it was always planted with only one crop. Despite the relatively poor numeric results, the method gives a fine visual approach of the ragweed infestation in Estrablin village.

DISCUSSION AND CONCLUSIONS

The idea of "using remote sensing to detect *Ambrosia*" was first mentioned by Asselin and Maupin (1998) who worked in Montréal (Canada). They tested a hyperspectral sensor but due to technical problems, they did not achieve their goal. Using a spectroradiometer, Maupin and Boivin (2001) built a spectral database of plant and mineral cover. Analysis of these data showed that inside *Ambrosia* population, spectral signatures are not homogeneous, some confusion between *Ambrosia* and other species like *Artemisia* or *Asclepias* exists and useful wavelength to distinguish *Ambrosia* from other associated species ranged between 750 and 875 nm. This last conclusion confirms our own work which showed that *Ambrosia artemisiifolia* is detected in red and NIR.

Table 3. Error matrix. Analysis of data recorded in Estrablin village (Isère department, France, 2005).

Result Classes		Ground truth																		
Culture (%)		Wheat				Maize				Sunflower		Colza		Fallow land				Others		
	Infestation	None	Low	Moderate	High	None	Low	Moderate	High	Low	Moderate	Low	Moderate	None	Low	Moderate	High	None	Moderate	High
Wheat	None	**2.4**	1.05	0.76	0.44	0	0.03	0.53	0.02	0.01	0.02	0	0	0	0	0.01	0	0	0	0
	Low	0.89	**3.05**	0.18	0.35	0	0.04	0.47	0	0.13	0.28	0.02	0.02	0.01	0	0	0	0	0	0.07
	Moderate	1.29	1.04	**3.57**	0.6	0	0.03	0.48	0	0.02	0.49	0.01	0.21	0	0	0	0	0.01	0.01	0.01
	High	0.41	0.59	0.21	**2.19**	0	0	0.02	0	0	0.07	0.01	0.02	0	0.01	0.03	0.01	0.01	0.02	0.07
Maize	None	0.03	0.05	0.02	0.03	**0.44**	2.95	3.4	0.09	0.06	0.26	0	0.01	0.03	0	0	0.01	0	0	0.02
	Low	0.04	0.09	0	0	0.05	**4.61**	5.46	0.07	0.16	0.4	0	0.02	0	0	0	0.01	0.02	0	0.01
	Moderate	0.01	0.03	0.04	0.03	0	0.29	**1.2**	0.04	0.03	0.03	0	0	0	0	0	0	0.02	0.01	0.01
	High	0.02	0	0	0	0.02	2.93	2.2	**0.95**	0.04	0.21	0	0	0	0	0	0	0	0	0
Sunflower	Low	0	0.01	0.04	0.01	0	0.03	0	0.01	**10.98**	6.17	0.03	0	0	0	0.02	0	0	0.03	0
	Moderate	0	0	0	0	0	0.09	0.02	0	2.23	**9.8**	0	0.03	0	0	0	0.02	0	0	0
Colza	Low	0.01	0.07	0.09	0.03	0	0	0.03	0.01	0.41	0.38	**1.15**	0.22	0	0	0.03	0	0	0.03	0.01
	Moderate	0.04	0.36	0.44	0.26	0	0.02	0.06	0	0.25	0.22	0.49	**1.73**	0	0	0.02	0	0	0.01	0.04
Fallow land	None	0.02	0.16	0.06	0.09	0.01	0.14	0.14	0.01	0.11	0.11	0.01	0.04	**0.25**	0	0.05	0.02	0	0.1	0.13
	Low	0.05	0.07	0.1	0.54	0	0.01	0.01	0	0.01	0.09	0	0	0	**0.15**	0.01	0.04	0.09	0	0
	Moderate	0.26	0.8	0.34	2.99	0	0.02	0	0	0.02	0.08	0.02	0.12	0.02	0.02	**1.06**	0	0	0.02	0.02
	High	0	0.02	0.08	0.74	0.01	0.22	0.16	0	0.03	0.05	0	0	0.01	0	0.04	**0.49**	0.02	0.07	0.09
Other (%)	None	0.06	0.08	0.08	0.37	0	0.24	0.29	0.01	0.03	0.02	0	0	0.01	0	0.03	0.05	**0.17**	0.03	0.03
	Moderate	0	0.01	0.01	0.03	0.01	0.22	0.25	0.02	0.21	0.4	0.06	0.03	0	0	0.03	0.02	0	**0.39**	0.1
	High	0.03	0.16	0.07	0.57	0	0.16	0.17	0.01	0.17	0.19	0.02	0.06	0.01	0	0.01	0	0	0.02	**0.11**
% correctly classified pixels		43	40	58	24	83	38	8	77	74	51	63	69	73	82	80	74	53	53	15
% correctly classified pixels per crop		67				86				85		83		86				48		

We are encouraged to continue our studies based on Spot sensor which records data in wavelengths which are closer (red [610 – 680 nm] and NIR [780–890 nm]).

In the Rhône-Alpes Region, the studied zone is located in an agricultural zone and the first difficulty was the intermingling of ragweed and crops. The satellite sensor captures a mixed signal from both the luminance of ragweed and the one of the crop. To evaluate the infestation importance, we need to know the spectral response of ragweed and of all other species growing in the studied zone. These data can be obtained by a direct measure with a spectroradiometer or by a ground truth to delineate training zones.

The method used works well for areas smaller than 10 km^2. For larger areas it needs to be improved in two ways. First, by taking into consideration the characteristics of satellite sensors. Satellites record data from three different entities: crop, ragweed and soil. For small areas, such as a village, the soil is quite homogeneous and its influence is weak. For larger areas, soil nature differs and we have to take into account ragweed populations intermingled with crops for a better detection of ragweed infestations. Second, by taking into account the multitemporal data acquisition. The ideal time to get images depends on the development of *Ambrosia* and meteorological factors. Therefore, multitemporal acquisitions increase the success to get a good image quality. Moreover, following the growth of ragweed individuals for the whole vegetation season helps to distinguish it from other species which show less foliar development or whose colour turns into yellow. Our researches, which have begun in summer 2007, try to combine these two parameters and will open new avenues for the detection of *Ambrosia* infestation based on remote sensing data.

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