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FOREST MONITORING METHOD USING COMBINATIONS OF SATELLITE AND UAV AERIAL IMAGES. CASE STUDY - BĂLĂBĂNEŞTI FOREST

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Abstract

The increasing use of satellite faraway sensing for civilian use has proved to be the most cost effective means of mapping and monitoring environmental changes. From this point of view, these new tools are now essential in monitoring operations for vegetation and non-renewable resources, especially in developing countries. In today's literature a series of 262 spectral indices are defined to evaluate the vegetation health for a specific area. For the vast majority of these infrared spectral index values are included. Infrared recording devices are quite expensive. In this respect, the possibility of using only the visible domain should be experienced in order to reduce the operational costs. The main hypothesis comes from the fact that any changes in vegetation status cannot be reduced and described only by the infrared domain changes. This study presents the results of a general aim: to design, to investigate and to confirm a specific analysis method that uses only the visible RGB spectra by using historical recordings. With this main objective of getting a method with a minimal operational cost, in this regard a combination of two classical techniques was tested - satellite image monitor analysis and UAV high resolution images use. The further exposed method in this paper suggests the joining of the two monitoring methods in successive phases: in the first step resolution suitable satellite images were used in order to succeed in building a forest model. The model confirmation and the validation process is done in the second stage by using specific UAV flights for high resolution images acquiring over a series of gauging points from the studied area. The presented case study is that of Bălăbăneşti Forest from Galati County. The study was conducted between 2005 and 2016. Preliminary results on the composition evaluations are promising and the research is ongoing.

***Keywords**: Forest model; RGB spectra; Minimal operational cost; Model validation.*

Introduction

Environmental monitoring and especially prevention of degradation is currently a major challenge. Soil degradation, reduction of forested areas, global warming, etc. all generates

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effects difficult to assess in the future. In this respect, any effort to identify changes in environmental monitoring and ground is welcome.

In the last years, the natural disasters' damages recording action has become a priority concern of governments and international organizations. This worry is justified by the fact that the recorded damages losses sometimes exceed existing budgets and national plans for economic and social development.

Indeed, the European Commission's official statistics (http://ec.europa.eu/) show explosive growth of the costs of the damages from natural hazards in the last decades. Although for hundreds of years of climate phenomena that caused catastrophic landslides or floods occur with approximately the same frequency and intensity, the damages increase in price [1, 2].

For all these reasons, the necessity of adopting proactive measures against climate change which increasingly affects our life appears. Amongst these measures, forest protection appears to be a highly effective measure [2, 3]. This is neither new, nor innovative. By protecting forests, many helpful effects were recorded over time, starting with soil stabilization against landslides and ending of course with the incomes against desertification and soil degradation [3-7].

Initially the surveillance and monitoring methods were based on the direct study and empirical measurements in the field [8, 9]. In the contemporary era, especially in the last 50 years, surveillance techniques have multiplied using different devices and procedures [10-13]. If many years ago, the people had had to cross the lengthy trails through the woods to inspect every corner, after 1935 aerial surveillance methods using self-propelling means such as aircraft or balloons were tuned [14-20]. This moment marks the birth of practical and specialized services organizations in observing the global parameters of vegetation and forest development level in an automatically mode (http://www.nnvl.noaa.gov/).

Nowadays, many new research directions are being explored in the monitoring [21-24] and planning of forest development through modern procedures [25, 26]. In this respect, more attention is paid on tourism and ecotourism and on the exploitation of the forest touristic potential [25, 26]. At the same time, with the evolution of the monitoring methods [27, 28], a number of basic parameters for the characterization of forested habitat were standardized [29-31] into an international system: stand height, forest density, forest composition, etc. [32-39].

In the last 20 years, in literature a certain trend to use in combination to classical land measurements, additional analysis and photogrammetrically investigations of aerial images for better evaluation of the trees' average height and for composition of forested areas can be observed [40-44].

In general, photogrammetric standard methods in literature were focused especially on the evaluation of the average height of the tree stem volume, the medium size of the crown or on the density and texture values [31, 45] derived from matching the aerial photogrammetric digital images or high-resolution spectral analysis [46-48].

A new direction for aerial photography use is represented by the methods that focus on assessment of forests' composition and it's time evolutions [21-24]. In this respect, the identification of dynamical parameters for distribution of different tree species using aerial photography is now an important aim for the scientific research work. The present study is part of this more general domain that aims to identify and assess the distributions' evolution for various tree species using aerial photographs.

In this respect, the present research proposes to define a new investigation method that uses only the visible RGB spectra at different time moments. The objectives of the study were to find out the forest composition using the RGB satellite images in combination with particular UAV high resolution imagery. The initial hypothesis was that by comparisons between chronologically ordered RGB spectra records, could describe the vegetation changes and its developments in a given area. Looking for a minimal cost solution, we had to use images that contain only RGB visible spectrum. Such images are certainly less purchased from specific services and could be easily obtained from a series of scientific services for free. Based on these chronological RGB spectrum records the aim was to build a spatial vegetation model. The model has to be then verified and validated through air flights upon some well-defined a priori chosen GPS control points. These flights made by our UAVs allow acquisition of high-resolution images that further are used to species identification and model calibration (Fig. 1).

Fig. 1. The UAV used in the high precision aerial monitoring process

This paper presents only the results on the composition identifying and its dynamics. Other additional obtained results obtained basing on this method will be the subject of future papers.

In this spirit, the present paper examines a critical insight into one of the contemporary used method in monitoring vegetation over large areas using satellite LANSAT photos type [40]. In this respect, in the next section is described our specific technique that has been developed in our Statistical Analysis and Cadastral Applications Laboratory (LASAC) from our European Centre of Excellence for the Environment – ECEE (https://erris.gov.ro/European-Centre-of-Excellenc-1). The method has been tested on a series of forestlands from Galati County and this paper presents the Bălăbăneşti Forest case study results.

The first innovative feature comes from the fact that we use georeferenced satellite images in three spectral bands in the visible spectrum of colour, avoiding the use of infrared band. This way we aimed to investigate the possibility of using images with reduced colour bands.

The second innovative characteristic lies in combining advanced analysis methods of colour satellite photos with high precision aerial monitoring methods using our UAV devices (Fig. 1). For this purpose we used two UAVs from our faculty endowment. Their wingspans and their payloads assure boarding of photo equipment. The aid of high-resolution images and the geo-referenced information allow precise identification of species within the woodland and thus a time distribution for different tree species [45, 46].

Materials and Methods

In a series of previous works, statistical analysis of reflectance spectra changes for different forestry systems were presented [2, 44]. In this respect, for any protected forest area, the RBG spectra analysis shows a certain linear evolution correlated with the proper vegetation growth rate [2, 42, 45]. This way, it was proved that for short time period (usually under 3 years), could be found out certain correlations and linear relations between RGB reflectance spectra values at different time moments [2, 42]. These results suggested that RGB spectrum use could be also a tool to describe the time evolution of forested areas. This idea was regularly met in literature [19, 20]. The problem of deteriorating correlations between the RGB spectra for longer periods of time was also analysed in literature [42, 45]. The non-linear solutions based on automated neural network were also presented in previous works [47].

After the demonstration of the existence of a colours' spectrum sensitivity related to changes that took place in a forest, it could be raised the question whether the performed colour analysis on satellite images is able to identify the tree species distribution. The answer is that this analysis cannot be used directly to identify the composition of a forest i.e. to determine the surfaces' weights occupied by different tree species. This study was made on a series of five forested areas from Galati County. The presented case study in this paper is the Bălăbăneşti Forest (Fig. 2). The proposed method consists of the following algorithm:

1) Satellite images of the studied area are taken at well-chosen time moments. For this step, images from other organisations which own this type of photos can also be used.

2) Satellite images are subject of a geo-referencing procedure and some initial processes on the resolution and different image parameters. Image J (https://imagej.nih.gov/ij/) could be easily used.

3) The RGB colour analysis is applied in order to find out the fundamental chromatic distribution in the three colour space representation and to identify the control points by using an inverse distribution function definition [42, 45]. This step is necessary for the model calibration phase. In this respect, all the pixels form the satellite picture are included into a database with 5 coordinates: three spatial coordinates (x and y) and (c_r, c_g, c_b) the RGB colours index values. Using this database, a phase representation in the RGB space could be attained by using a k-means clustering method [9, 37, 42] i.e. for given a set of N observations (v_1, v_2, …, v_N), where each observation is a d-dimensional real vector, k-means clustering aims to partition the N observations database into k sets (or accumulation domains) in order to minimize the within-cluster sum of squares (WCSS):

$$WCSS = \underset{S}{\arg\min} \sum_{i=1}^{k} \sum_{v \in S_i} \left| v - \mu_i \right|^2 \qquad (1)$$

where S={S_1,S_2, .., S_k} is the partition, {v_i} are the colours index values vectors and {μ_i} are the mean of points in the domain S_i i.e. the mass centres for each domain. The main reason is that the k-means clustering method seems to be more effective since many authors showed that "principal components are the continuous solutions to the discrete cluster membership indicators for k-means clustering" [49].

Fig. 2. The Bălăbăneşti Forest area studied

In this respect, using the RGB colours' coordinates these accumulation zones are constructed in this three-dimensional colour space and the mass centres for each domain define a conventional colour. These accumulation domains generate a set of conventional or elementary colours. All the points with slightly different shades of an elementary colour are included in the related accumulation domain corresponding to this identified dye.

4) The suitable algorithm can "reverse" the representative RGB connection between the colour space and the spatial coordinates, i.e. for each representative point in the colour space can be found the spatial coordinates (x, y) corresponding to the shades.

5) changing the number of clusters lead to a change in the structure of accumulation areas. In this way, the algorithm builds a number of different basic colours, depending on the size of the range set. Having a number of a priori established areas, related to specific zones occupied by different species of vegetation, the change of the clusters number will be done to correct separation of the chosen reference areas.

6) Based on an appropriate separation obtained during the stage above, maps of forest in these conventional or elementary colours' set could be constructed.

7) The obtained model is then verified and validated through air flights high-resolution aerial images upon the defined chosen control points.

Further a case study for the Bălăbăneşti Forest is presented.

Results and discussions

Field survey and data collection

The Bălăbăneşti village is located on the border between the Galati and Vaslui Counties. The first documentary mention of the Bălăbăneşti settlement is registered on the 5th December 1460 in an act of judgment given by Stefan cel Mare. The Bălăbăneşti forest is located near the Bălăbăneşti settlement, between these geographical coordinates: northern latitude of 46°02'48'' and 46°04'12'', respectively between eastern longitudes 27°41'24'' and 27°45'36'' (Fig. 2). The Bălăbăneşti Forest is placed in the northern part of the Galati County and has an area of 950 hectares. The main reasons for selecting this forest comes from the fact that Bălăbăneşti Forest has a simple composition and because the areas were sheltered during the study (Table 1). The Bălăbăneşti Forest mainly includes about 6 different species of trees. Surfaces and weights corresponding to each tree species were monitored in parallel to the ground (Table 1).

Table 1. Balabanesti Forest — general data of the forest

Area of study/ year	harvest rate (c. m. /year/ha)	Consistency	Density (No. specimens / ha)	Average growth rate (c. m. /year/ha)	Composition (%)
Balabanesti Forest 2005	2	0.830	975	5.20	42Sc 30Go 11Te 5St 3Fr 3Ca 6DT DM
Balabanesti Forest 2009	2	0.731	916	4.81	43Sc 27Go 15Te 5St 3Fr 3Ca 4DT DM
Balabanesti Forest 2010	1	0.730	804	4.53	48Sc 25Go 12Te 5St 3Fr 3Ca 4DT DM
Balabanesti Forest 2016	1	0.685	701	3.71	50Sc 20Go 13Te 5St 3Fr 3Ca 6DT DM

where Te - linden, Sc-acacia, St-oak and Go- sessile, DT- other species.

The study on this area was developed between 2005 and 2016 and the satellite images have been acquired in the same month – i.e. at the final part of May. The present study was made based on the pictures from 2005, 2009, 2010 and 2016. All these pictures were geo-referenced and the effective resolution was about 4 meters per pixel for each as described above.

The used satellite images were in three spectral bands in the visible spectrum of colour, avoiding the use of infrared band in correspondence with the proposed aim. A preliminary RGB colour analysis results in the 3D space representation shown in figure 3. For this representation, the building process was described above: each coloured pixel from the original satellite image get three coordinates in the RGB format. These RGB coordinates are stored in a specific 5 columns database, joining the spatial coordinate. Note that the number of colours identified is relatively small (Fig. 3), but because they are not kept rigorous nuances from one photo to another, direct species identification problems cannot be solved easily through the identification of representative. For example, in figure 4, the percentage weights were represented for the related domains represented in figure 3 in the RGB space. One may observe that the various shades easily change from one photo to another.

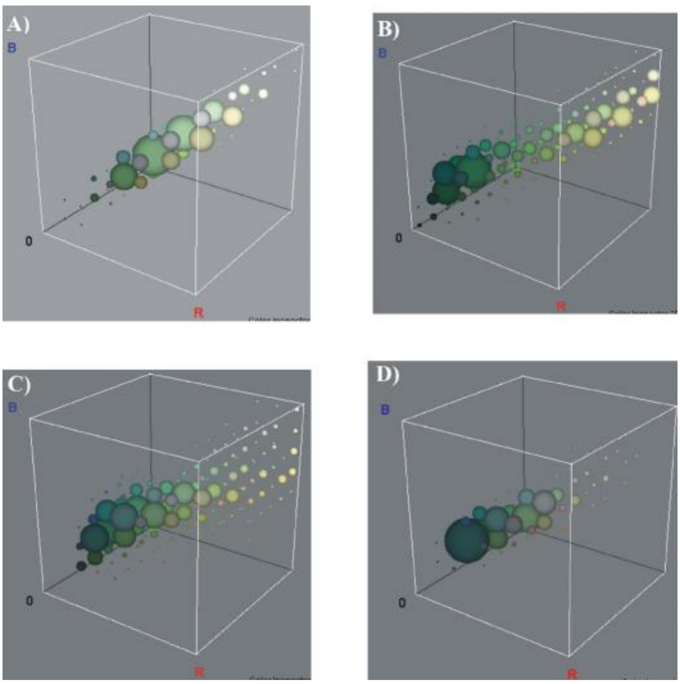

Fig. 3. The Bălăbănești Forest satellite images in RGB space representation of the colour analysis' results (A)-year 2005, (B) 2009, (C) 2010, (D) -year 2016

Following the algorithm described above, we can make a proper zone separation. In this respect, in figure 5 there is presented the a priori chosen reference areas in order to succeed in reaching the domain demarcation. The selection of the reference areas was made so that the vegetation in these zones presents a constant composition. This will help model calibration. Also, these a priori choices will perform the recognition and the identification of the linkages between conventional colours and the encountered vegetation species.

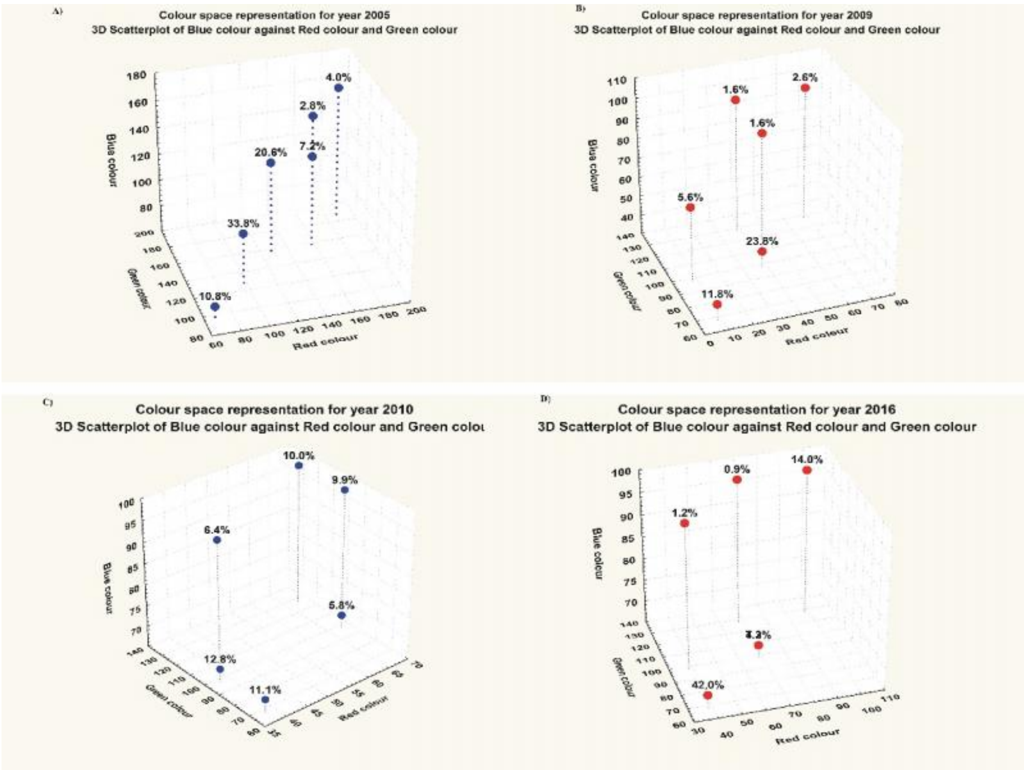

Fig. 4. The Bălăbăneşti Forest satellite images in RGB space representation of the weights for the principal identified colours (A)-year 2005, (B) 2009, (C) 2010, (D) -year 2016

Fig. 5. The Bălăbăneşti Forest – the reference chosen areas (2016)

Figure 6 presents the distribution for the first identified conventional colour in time. It is easy to observe the increasing density during the first time period between 2005 and 2009 and the decreasing density during the next time period between 2010 and 2016 (Fig. 7). figure 8 presents the distribution for the second identified conventional colour in time. This colour corresponds to the most prevalent species with a very interesting dynamics.

The last stage of our goal was to find out the correspondence between each conventional colour and the related species. This aim was achieved by using UAV high-resolution aerial images. For images with a minimum resolution of about 2 cm/pixel [42, 45], verification and validation of the model was thus achieved. figure 9 presents the six major conventional colours distributions of year 2016 in comparison with the rangers' land measurements. due to these reconnaissance flights alone the link between the elementary conventional colours and the species of trees that make up the forest composition can be acquired and validated.

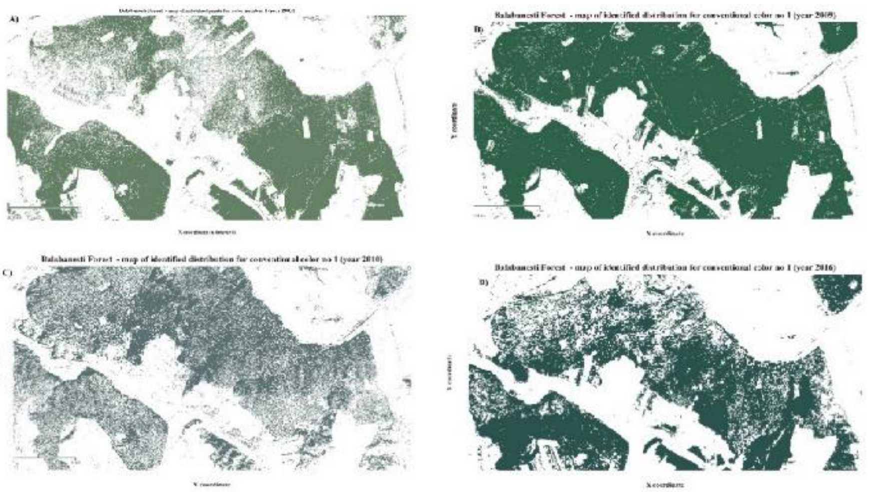

Fig. 6. The Bălăbăneşti Forest – distribution maps for the first identified conventional colour: a) year 2005; b) year 2009; c) year 2010; d) year 2016

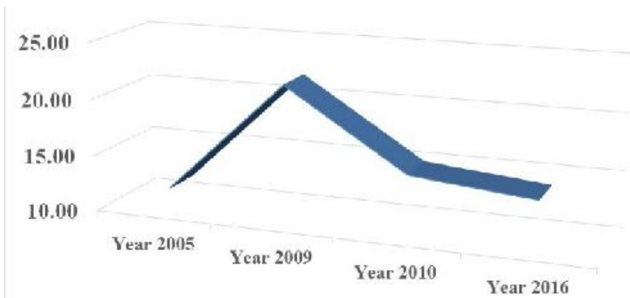

Fig. 7. The Bălăbăneşti Forest – spreading evolution for the first identified conventional colour during the time

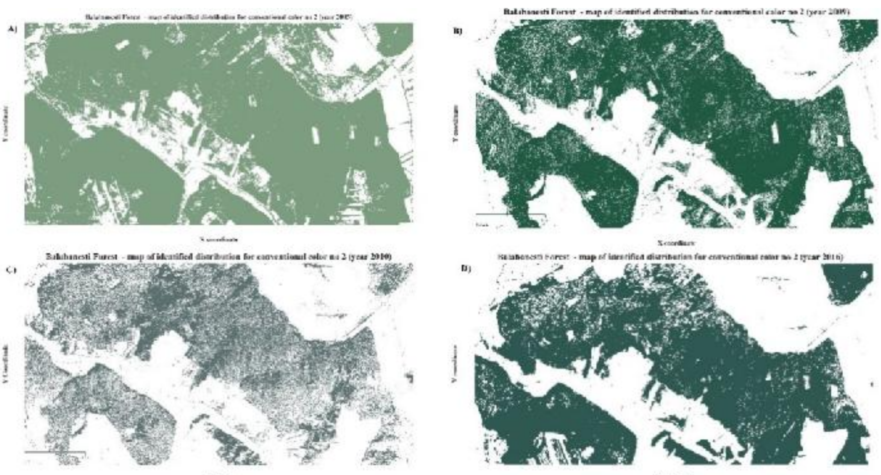

Fig. 8. The Bălăbăneşti Forest – distribution maps for the second conventional colour: a) year 2005; b) year 2009; c) year 2010; d) year 2016

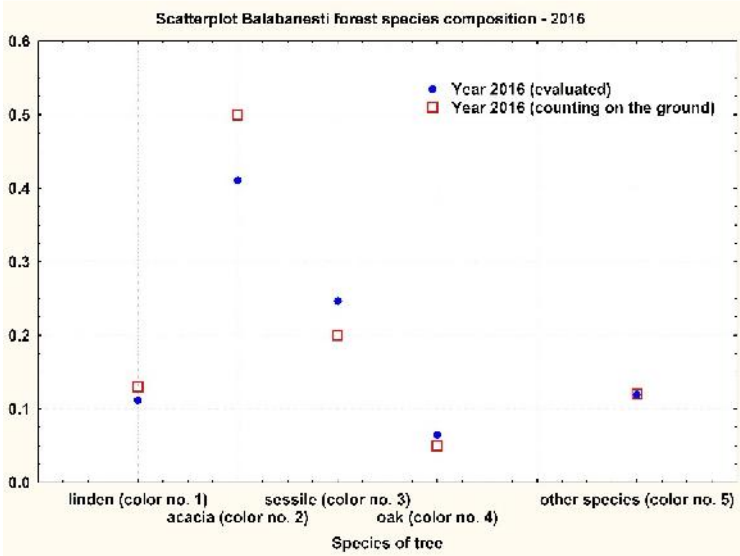

Fig. 9. Comparison of measured data and the record field- year 2016

As observed, the most widely distributed species is acacia - black locust (Robinia pseudoacacia), an invasive species.

Conclusions

In this article preliminary results that enrol in the global trend were exposed. Worldwide great emphasis on the use of monitoring and evaluation methods using means of remote sensing is put. This paper presents only the preliminary results of a method of evaluation of the forest composition and its dynamics.

The aim of our investigation was to test a minimal cost solution by combining two classical methods. Satellite images based methods involve operational costs. The methods based on the use of UAVs are cheap procedures but require relatively long time to obtain a global picture. In this respect, an effective combination encouraging preliminary results is proposed. The presented method is certainly improvable and the following versions will provide higher accuracy. There are noticeable differences of up to 15% in widely distributed species.

Large differences between the estimated values and the identified values in the field, especially for species with large distribution rate, may be explained partly by the slopes of the terrain. These terrain deviations from horizontality lead to noticeable differences. In the next versions we will refine the algorithm and we will reduce these influences.

As these results are promising and the research method is innovative, there will be further research on this topic. Considering the aim of the minimum operating price, we think that it has been achieved. The exposed method will be included in an expert dedicated system.

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