The Comparison of the Spectrum Modelling of Different Kinds of Meadows

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Abstract. Radiative Transfer Models are often used in plant monitoring. Vegetation monitoring of meadows is an important issue, especially on natural and semi-natural areas like meadows. The success in RT modelling is very dependent on the environment. The aim of the research was to compare modelling the spectrum on different kinds of meadows. The model PROSPECT was used. The field measurements have been done in Poland on heterogeneous meadows. The PROSPECT was used to model spectrum on different kinds of meadows: moved and unmoved, on dry and wet habitat, on highland and lowland terrain and also undersown with pulse plants and covered only with grass with smaller biomass. The field measurements were done in the Low Beskid Mountains and at the Mazowiecka Lowland. During the field measurements spectra were collected and the biophysical variables were taken and then recalculate to the input parameters: chlorophyll, water, dry matter and carotenoid content. In the end structural parameter was fixed for each polygon individually. From these parameters spectra were modelled using PROSPECT. The modelled spectra were compared with taken measurements and RMSE values were calculated. Depending on these four factors the modelling with PROSPECT is more or less successful. The biggest errors in modelling were noticed for 0,8-1,5µm region of spectrum. More errors were noticed for mountain meadows comparing with lowland meadows. For more biomass the RMSE values are getting smaller. The correctness of modelling is differently dependent on water content. Based on the results PROSPECT can be used for modelling heterogeneous meadows on leaf level.

Keywords. PROSPECT, meadows, spectrum modelling

1. Introduction

Vegetation analysis is an important problem in regional and global scale. Because of pollution of the environment and changes in the ecosystem plant monitoring is very important. Remote sensing data can be easily used to plant monitoring. That kind of method is much faster and more reliable than traditional approaches.

Spectrometry analyses the interaction between radiation and object and it uses measurement of a spectrum. Each object emits and absorbs different quantity of radiation. It is possible to recognise an object and check its characteristics analysing the spectrum. These kinds of researches are often used for vegetation analysis because of an opportunity to explore structure, chemical composition, cells structure, biomass, water content and plant condition [1].

The aim of the study was to check is it possible to simulate spectra heterogeneous meadows using Radiative Transfer Model and how successful is the Radiative Transfer modelling dependent on different kinds of meadows.

The subject of the researches is Polish heterogeneous meadows. Meadows are vegetated primarily by: grass, herbs and pulse plants and have natural or semi natural origin, but human usage of the meadows determines its proper functioning. Grasslands, which consist of meadows and pastures, cover 10% of Poland. About 70% of the grasslands are used by pasturing or moving. What is moreover, in Poland meadows are mostly extensively used, crops from meadows, hay and green forage, are very low. From the ecological point of view the meadows in Poland are floristically and morphologically very diverse. Most of the areas have similar mixture of plants.

Meadows monitoring is essential to farming and ecology. The grasslands are habitat of rare plant species and animal, also water is accumulated there. Nowadays the ecological farming has become more popular and because of that, plant monitoring and crops forecasting is also getting more important.

To canopy analysis two approaches are used: statistic and modelling [2]. In statistic approach, biophysical parameters calculated from the image are correlated with reflectance or transmittance from field measurements. In second approach physically based model is used to represent a photon transport inside leaves and canopy [3].

Radiative Transfer Models are often used in plant monitoring. The Radiative Transfer Models are physically based models which describe the interactions of radiation in atmosphere and vegetation [2]. RTM are based on the radiative transfer equation and three parameters: reflection, transmission and absorption. The interactions of electromagnetic radiation with plant leaves depend on the chemical and physical characteristics of leaves [2]. A canopy can be described as a homogeneous layer consists of leaves and spaces. The absorption in ultraviolet and visible light is dependent on the pigments in leaves. A structure of the leaves and water content has an influence on the absorption, transmission and reflection in near and middle infrared.

The Radiative Transfer Models are algorithms which vary by input and output parameters, the level of the analysis, kinds of plants and other modifications of the model. The input parameters are biophysical parameters, the output – spectral characteristic of the plant. Models are used on two levels: single leaf and canopy. Many adjustments can be included: for example correction of a hot spot effect. Models are designed to different vegetation types like forests, meadows, cereal. The success in RT modelling is very dependent on the environment and its structure. Good results were noticed for homogeneous canopy, worse for heterogeneous. In these analysis PROSPECT model was used, which describes plants in leaf level [4].

In most of the studies the Radiative Transfer Models are used to homogeneous vegetation analysis. Radiative Transfer modelling is rarely used to meadows, because this kind of ecosystem is normally rather heterogeneous and modelling is quite difficult. Many parameters influence the correctness of modelling the spectrum. In this study four factors are analysed: relief (mountain or lowland meadows), dry and wet habitat, haymaking, and undersowing with pulse plants and covered only with grass with smaller biomass.

2. Methods

The first stage was to choose model appropriate for meadows. PROSPECT-5 was chosen, because of its simplicity and good results in meadows modelling [5, 6]. PROSPECT describes the multidirectional reflectance and diffusion on leaf level [4]. It simulates the leaf hemispherical reflectance and transmittance. Model allows simulating the leaf hemispherical reflectance and transmittance in 400-2500nm range. It is mainly used to the rather homogeneous vegetation types like cereals. It is widely used to describe plants and vegetation analysis [5, 6, 7, 8, 9]. It is often employed with other models that describe whole canopy. In practise, on leaf level PROSPECT model was applied to estimate chlorophyll content, Leaf Ares Index [5, 6] and water content [10]. It was also used in methodology analysis, in particular in data simulation [4]. More often it was used to calculate input parameters to other Radiative Transfer Model or it was combined with other agricultural models [8]. Model was used with SAIL to model canopy in heterogeneous grasslands [5]. The models were inverted to retrieve chlorophyll content and Leaf Area Index based on hyperspectral measurements.

PROSPECT was also used to analyse semiarid natural grasslands to estimate LAI by inverted the model [11].

In the model assumptions, plant has a structure of many straight surfaces of leaves without spaces or atmosphere [4]. Every surface has a specific refraction and absorption properties that are dependent on content of: water, pigment (mainly chlorophyll), proteins, cellulose, lignin, starch and biomass [3]. Leaf has the same properties on both sides; the reflection from the leaves is Lambertian. The input parameters of the model are: chlorophyll and carotenoid content, water and dry matter content and also structural parameter, that describes the leaf structure and complexity. The output parameters are reflectance and transmittance in 0,4-2,5μm.

The field measurements were done on heterogeneous meadows on two study sites: in the Low Beskid Mountaines and at the Mazowiecka Lowland. Measurments in the Low Beskid Mountaines were done in July 2009 on 7 polygons. Minimum area of each field was equal 1000m^2. The measurements took place in slope and hilltop (polygons marked with T) and valleys (polygons marked with P).

Second part of measurements was done at the Mazowiecka Lowland in July and August 2010 on 51 test polygons. Each of them has at least 100m^2. The measurements were done on three different habitats: rather wet, intensively used at southern part of the lowland (polygons marked with D), dry and extensively used at the northern part (polygons with R) and mixed at the western part (polygons with S).

During the researches spectrum was collected for each polygon using ASD FieldSped FR 3, Chlorophyll Content Index was measured using Chlorophyll Content Meter-200 and Leaf Area Index using LAI Plant Canopy Analyzer. Also the fresh biomass was collected to calculate water and dry matter content and vegetation was mapped.

After field measurements 22 polygons were selected to further analysis. Chosen polygons were diverse and represented four partition of meadows: mountain (7 polygons) and lowland (15 polygons); moved (10 polygons) and unmoved (12 polygons); undersown with pulse plants, with a lots of biomass and (7 polygons) and vegetated only with grass (15 polygons) and on fresh (16 polygons) and wet habitat (6 polygons).

All measured vegetation parameters for 22 polygons were recalculated to four input variables: chlorophyll content (in μg/cm^2), carotenoid content (in μg/cm^2), water content (in cm) and dry matter content (in g/cm^2). The structural parameter was fixed for each polygon individually.

The input parameters for each polygon were put into the PROSPECT and reflectance and transmittance value were calculated for 0,4-2,5μm. Than modelled reflectance values were compared with spectra collected during the field measurements. The root-mean-square error was calculated for whole range of spectrum 0,4-2,5nm and four ranges: 0,4-0,6μm, 0,4-0,8μm, 0,8-1,5μm and 1,5-2,5μm. In 0,4-0,6μm all five parameters have influence on the shape of the modelled spectrum, in visible light from 0,4 to 0,8μm all parameters have influence, but chlorophyll content is dominant. In near infrared dry matter and water has the big influence, but in 1,5-2,5μm the water has dominant impact.

In the end the value of RMSE for whole spectrum and the ranges were averaged for different kinds of meadows. Also the meadows were divided on three classes depends on the water content and LAI. In each of three groups the RMSE values were averaged.

3. Results

Generally spectra for meadows were properly modelled using PROSPECT (Fig. 1). The RMSE value for 0,4-2,5μm range was from 0,017 to 0,061. The average value of root-mean-square error was 0,028 for whole polygons. The biggest error (0,055) is for 0,8-1,5μm, where dry mater content has the biggest influence. The smallest error is for 0,4-0,6µm (0,018). For visible light from 0,4 to 0,8µm the RMSE was equal 0,042. A little bigger was for 1,5-2,5µm range – 0,045. The best modelled spectrum (RMSE=0,014) was for undersown meadow at lowland with a lot of biomass with clover (D4). The worst modelling (RMSE=0,061) was notice for moved, meadow in mountain with little biomass, vegetated only by grass (polygon T9).

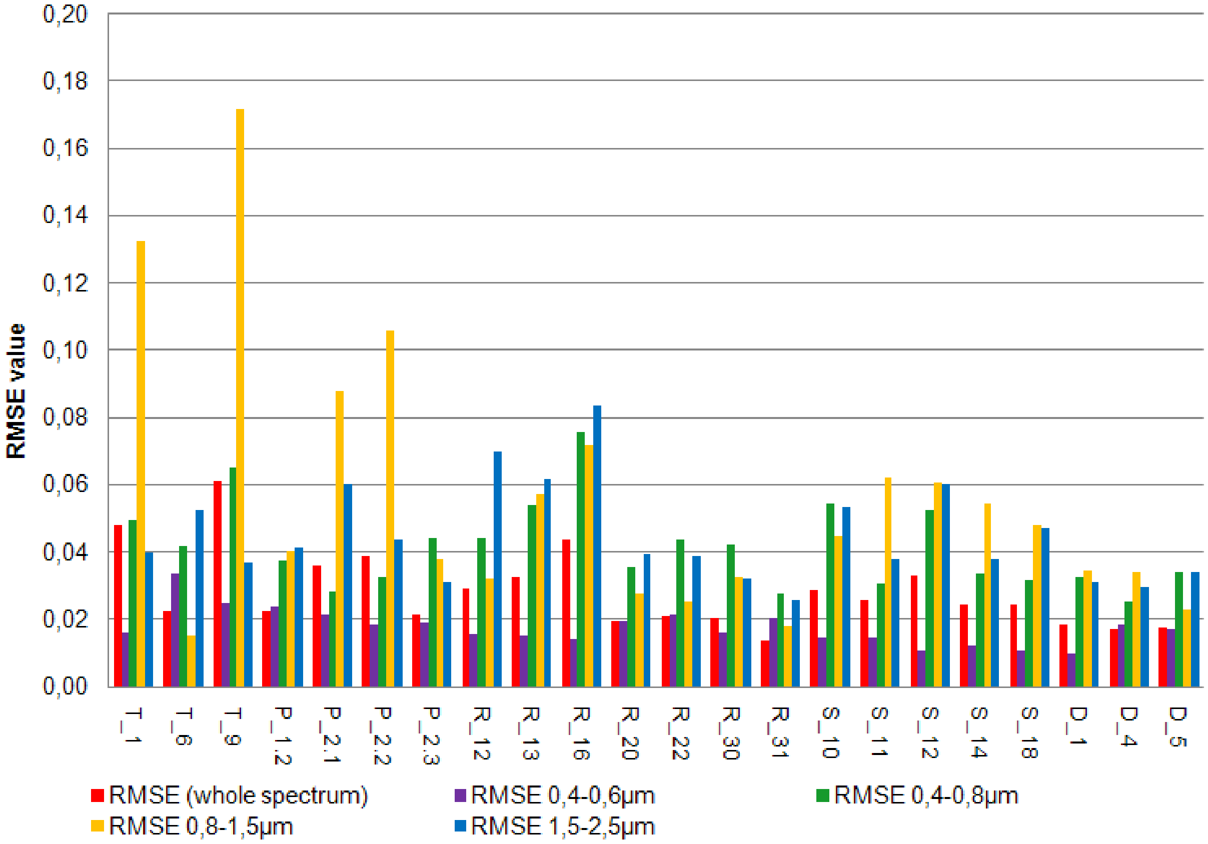

Figure 1: The RMSE values for all analyzed meadows

Then modelling was analyzed dependent on relief (Fig. 2). Meadows at lowland were better modelled (RMSE for range from 0,4 to 2,5µm for lowlands was equal 0,025 and for mountains 0,036). Big differences in RMSE (0,043) were noticed in 800-1500µm range. Small differences appeared for other ranges.

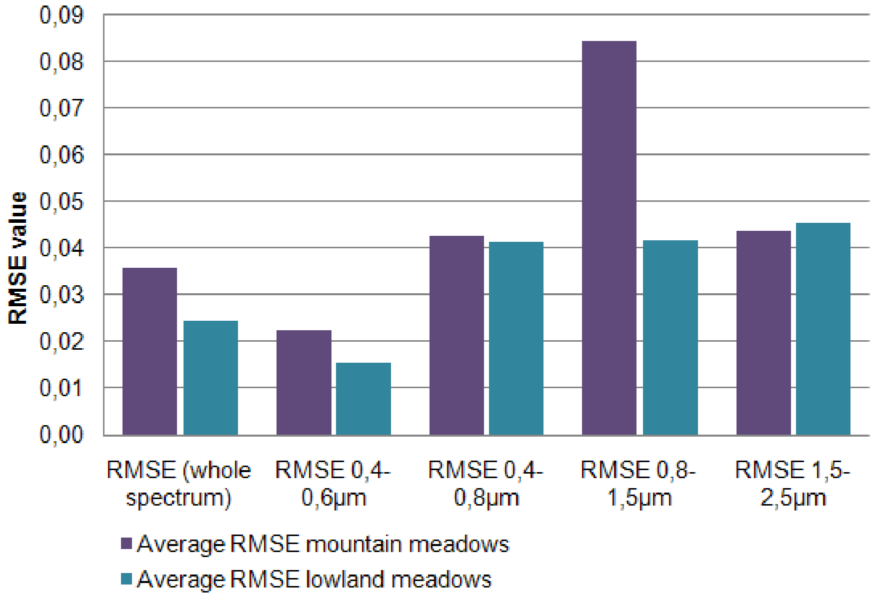

Figure 2: The average value of RMSE for mountain and lowland meadows

The wetness of habitats was analyzed. Better modelling was noticed for fresh meadows, where RMSE for range from 0,4 do 2,5µm was equal 0,027 (Fig. 3). The biggest difference of RMSE values (0,019) were for 1,5-2,5µm range. Bigger errors in modelling this range can be related to grater water content for wet meadows.

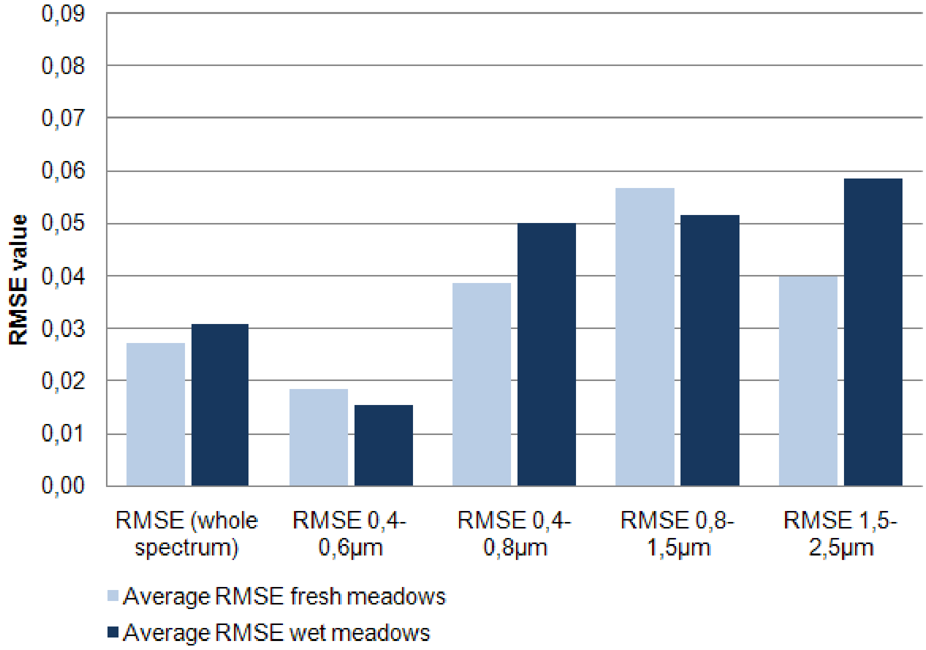

Figure 3: The average value of RMSE for fresh and wet meadows.

The RMSE value was also analyzed depend on moving the meadows (Fig. 4). A little better modelling was for unmoved meadows (RMSE for range from 0,4 do 2,5µm was equal ,026), comparing to moved meadow, where the biomass is removed (RMSE=0,031). The biggest difference of RMSE (0,03) was in 0,8-1,5µm range, where dry matter has the biggest influence. In other ranges the differences were rather small.

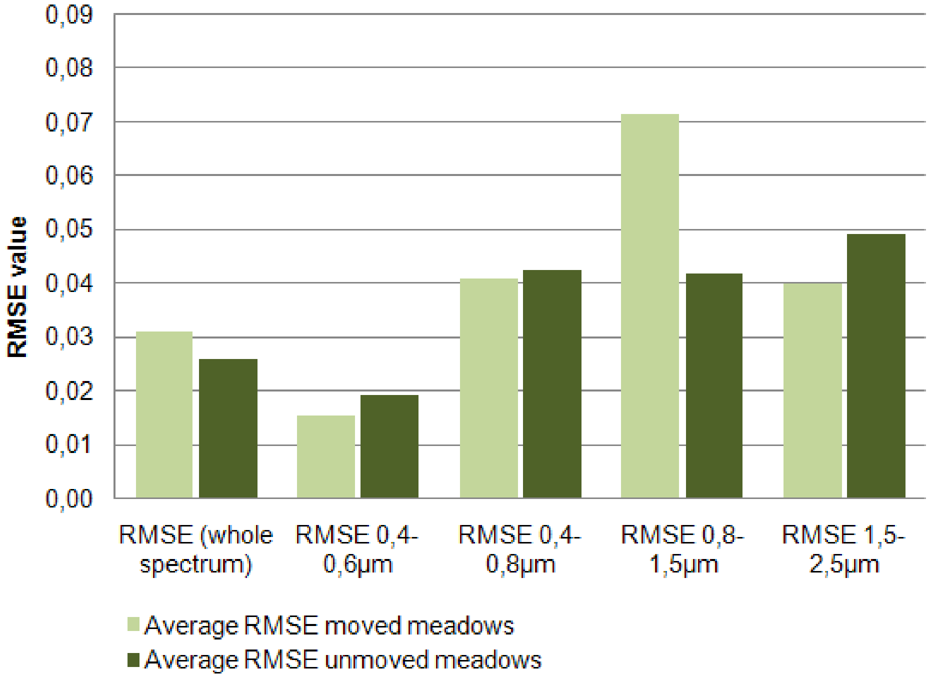

Figure 4: The average value of RMSE for moved and unmoved meadows

Also the influence of planting plants with more biomass was analyzed (Fig. 5). Better modelling was noticed for undersown meadows with clover and other pulse plants (RMSE for range from 0,4 do 2,5µm was equal 0,021) than for meadows vegetated with grass only (RMSE equal 0,032). The biggest difference for RMSE (0,032) was for 0,8-1,5µm. The differences in modelling were noticed for whole ranges of spectrum. Generally, meadows with more biomass are better for modelling.

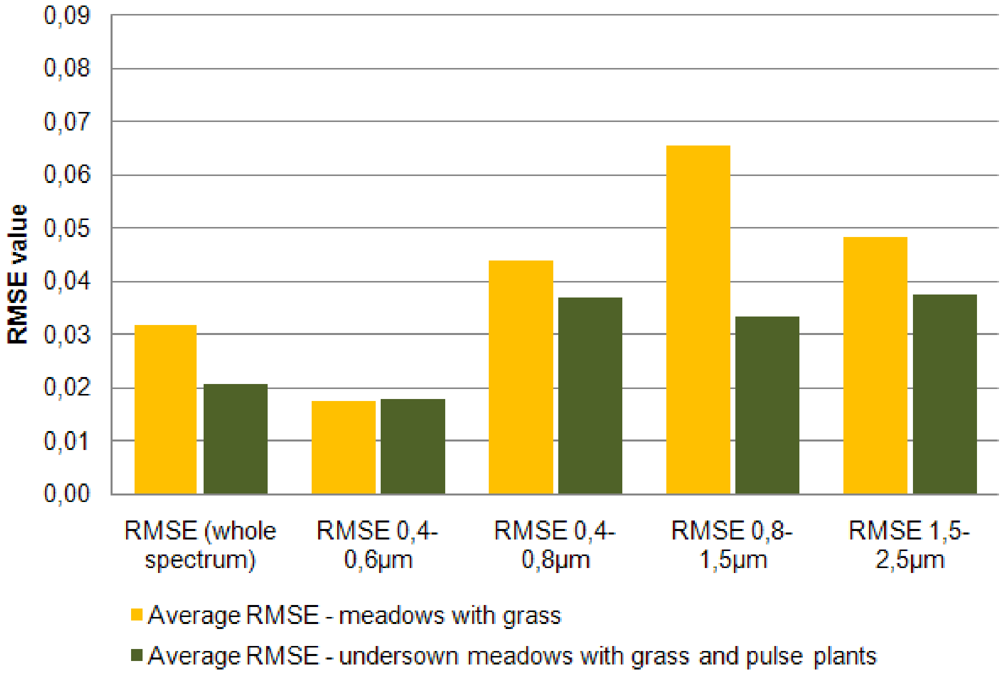

Figure 5: The average value of RMSE for meadows with smaller and larger biomass

The same conclusion was noticed for meadows with different values of Leaf Area Index (Fig. 6). The biggest errors were for meadows with LAI below 2 – with small biomass (RMSE=0,036 for range 0,4-2,5µm) The big differences in modelling were only in 0,8-1,5µm range – RMSE from 0,046 to 0,088. For others range the differences were rather small.

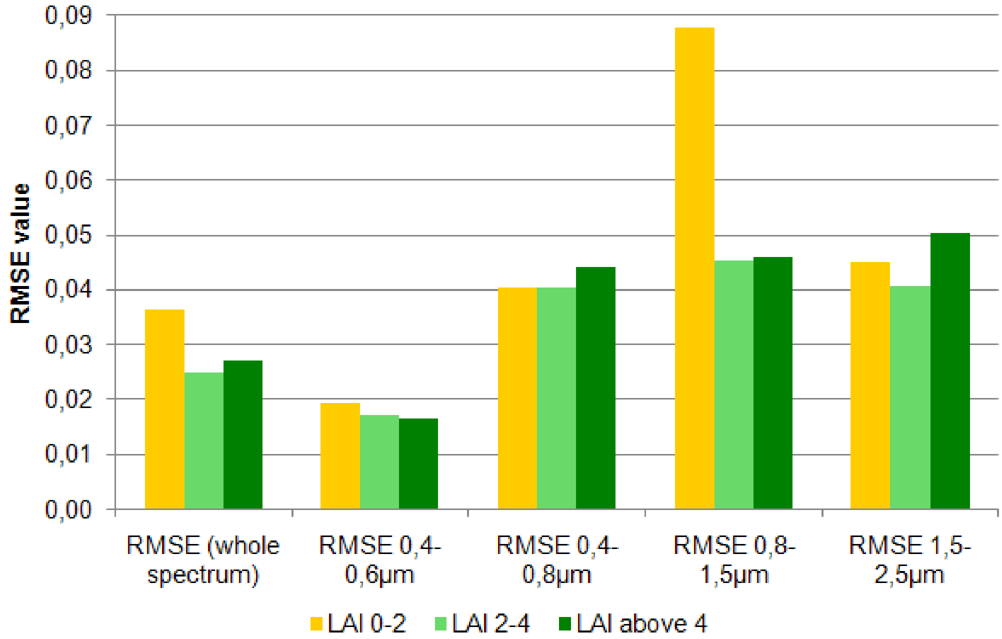

Figure 6: The RMSE values for different LAI

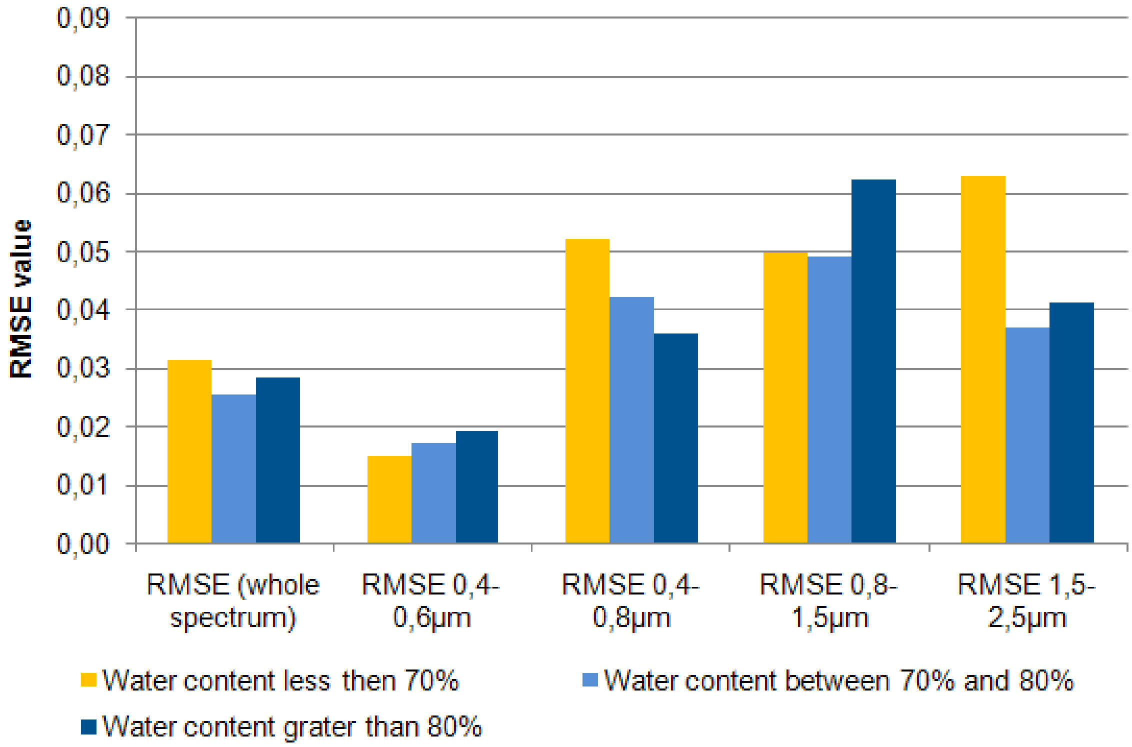

Figure 7: The RMSE value and water content

The correctness of modelling was differently dependent on water content (Fig. 7). For whole range the differences in RMSE were rather small: from 0,025 (water content in plants between 70 and 80%) to 0,032 (water content in plants less than 70). The biggest difference of RMSE was in 1,5-2,5µm range, where for the lowest water content error was the biggest. In visible light (0,4-

0,8μm) and 1,5-2,5μm for larger water content the modelling was more correct. In 0,8-1,5μm range larger water content was connected with bigger errors in modelling.

4. Conclusions

Based on the results heterogeneity does affect on the results, but other factors have bigger influence. The most important are the wetness of habitat connected with water content and amount of biomass. More errors were noticed for mountain meadows than for lowland meadows. The biggest errors in modelling were noticed for 0,8-1,5μm region of spectrum. For more biomass (larger LAI value and addition of pulse plants like clover) the RMSE values are getting smaller. Also removing biomass by haymaking worsen modelling of the spectrum, especially in 0,8-1,5μm region. Better modelling was noticed for plants that grow on fresh, not wet, habitat. Higher water content cause errors in 0,8-1,5μm region, but in visible and in 1,5-2,5μm the error is smaller.

Model PROSPECT can be used for modelling heterogeneous meadows on leaf level. Also other authors have successful used PROSPECT in natural grassland modelling [6, 11].

To make improvements to the modelling more polygons should be measured. Some kinds of meadows were not sufficiently represented. Also to proper model a spectrum on canopy level PROSPECT must be connected with other models like SAIL.

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