Delivery report

TerrA-P: Development and validation of a global GPP/NPP model using MERIS and Sentinel-3 data

Validation report

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SUMMARY

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LIST OF ACRONYMS

ABP	Above Ground Production
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GPP	Gross Primary Productivity
ICL	Imperial College London
LST	Land surface temperature
MERIS	Medium Resolution Imaging Spectrometer
UA	Universiteit Antwerpen
VITO	Vlaamse Instelling voor Technologisch Onderzoek

CHAPTER 1 DEFINITION

1.1. SCOPE AND OBJECTIVES

This document reports the results of the model validation at global scale against in-situ observations of ABP. It focuses on the validation of model simulations based on MERIS fAPAR input data.

1.2. APPLICABLE DOCUMENTS

[AD3]	Algorithm Theoretical Basis Document v2.2

1.3. CONTENT OF THE DOCUMENT

The validation report is organized in the following way:

- **Chapter 2** details on the validation approach using in-situ data.
- **Chapter 3** results of the model performance at global scale.

CHAPTER 2 ABP DATA DESCRIPTION

The point level ABP data were derived using the model described ATBD v2.2 [AD3].

The ABP was calculated by using Aboveground Production Efficiency (ABPE), the ratio of annual ABP to annual GPP.

The details of the input data to model ABP are provided in Table 1.

Parameter	**Source**
Daily incoming radiation [kJ/m2/d]	ECMWF, 10-daily averages at 0.25° grid
Average water vapour pressure [hPa]	ECMWF, 10-daily averages at 0.25° grid
fAPAR [-]	MERIS GVI, 1 km, 10-daily
LST [°C]	AATSR level 2, 1 km, cloud-free daytime observations, gap-filled and Swets smoothed
CO_2 concentration	Moana Loa Laboratory

Table 1: Input data for GPP estimation.

CHAPTER 3 VALIDATION APPROACH

This chapter describes the validation approach of the model simulations. The point location model simulations are validated with in-situ data of Aboveground Biomass Production (ABP).

3.1. VALIDATION AGAINST IN-SITU DATA

This validation aims to evaluate the performance of models in simutating annual aboveground biomass dynamics for forests and grasslands.

The validation was performed for sites and years available from in-situ biomass dataset against model simulations performed for years 2007 and 2008. In particular, in-situ average annual ABP were directly compared to the average annual ABP obtained from model simualtions. More details on “Site selection” and data quality are reported in the section 3.1.1. shows the geographical distribution of the sites selected.

3.1.1. DESCRIPTION OF THE IN-SITU BIOMASS PRODUCTION DATASET

For the validation of ABP we used a dataset recently released by the UA partner of this consortium (UA, Luyssaert et al 2007, GCB, Vicca et al 2012, Ecology Letters, Campioli et al 2015, NatGeo). This dataset is best suited for validation purposes because (i) it provides quality-controlled data for both aboveground, (ii) it provides standardized uncertainty estimates, (iii) provides ecosystem level data (e.g. dominant and codominant species, overstory and understory) compatible with the spatial footprint of the FLUXNET 2015 sites, thus comparable to remotely sensed data and (iv) provides NPP data paralleled by GPP for the same year of measurements for a subset of sites. This dataset is published and has been made publically available (Campioli et al 2015 and Vicca et al 2012).
From this dataset only sites with an homogenous footprint in the pixel area were considered. We considered 80 forest sites and 16 grassland sites. Table 2 list the sites selected as ideal sites for the validation of ABP.

Site	Latitute		Longitude		Plant Funcional type
CN-Hab-F01	37.6133	N	101.305	E	grasslands
CN-yao-D01	44.75	N	123.75	E	grasslands
CN-yao-D02	44.75	N	123.75	E	grasslands
RU-ha1-F01	54.7252	N	90.0022	E	grasslands
US-sgs-D01	40.82	N	104.77	W	grasslands
US-Spe-D01	36.6	N	99.58	W	grasslands
US-Spe-D02	36.6	N	99.58	W	grasslands
IE-dri-D01	51.98	N	8.75	W	grasslands
US-jrn-D01	32.6	N	106.75	W	grasslands
US-Kes-D02	34.98	N	97.52	W	grasslands
US-Kon-D02	39.0822	N	96.5603	W	grasslands
US-Kon-D03	39.0822	N	96.5603	W	grasslands
US-osg-D01	36.95	N	96.55	W	grasslands

US-osg-D02	36.95	N	96.55	W	grasslands
Andrews1	44.26	N	122.2	W	forests
Andrews10	44.25	N	122.2	W	forests
Andrews11	44.23	N	122.17	W	forests
Andrews12	44.26	N	122.18	W	forests
Andrews2	44.25	N	122.2	W	forests
Andrews3	44.26	N	122.2	W	forests
Andrews4	44.25	N	122.2	W	forests
Andrews5	44.23	N	122.18	W	forests
Andrews6	44.25	N	122.18	W	forests
Andrews7	44.27	N	122.22	W	forests
Andrews8	44.27	N	122.23	W	forests
Andrews9	44.26	N	122.19	W	forests
Bayreuth/WeidenBrunnen	50.15	N	11.87	E	forests
CascadeHead(1)	45.05	N	123.97	W	forests
CascadeHead(1A)	45.05	N	123.97	W	forests
CascadeHead10	45.07	N	123.89	W	forests
CascadeHead11	45.08	N	123.9	W	forests
CascadeHead12	45.04	N	123.9	W	forests
CascadeHead2	45.1	N	123.9	W	forests
CascadeHead3	45.11	N	123.88	W	forests
CascadeHead6	45.09	N	123.88	W	forests
CascadeHead7	45.09	N	123.88	W	forests
CascadeHead9	45.07	N	123.89	W	forests
Collelongo	41.85	N	13.59	E	forests
Dooary	52.95	N	7.25	W	forests
Hainich	51.08	N	10.45	E	forests
Harvard	42.53	N	72.17	W	forests
Hesse	48.67	N	7.07	E	forests
Hyytiala	61.85	N	24.3	E	forests
Juniper	44.29	N	121.33	W	forests
Loobos	52.17	N	5.74	E	forests
Metolius	44.42	N	121.67	W	forests
Metolius1	44.44	N	121.57	W	forests
Metolius10	44.5	N	121.62	W	forests
Metolius11	44.42	N	121.61	W	forests
Metolius2	44.45	N	121.69	W	forests
Metolius3	44.43	N	121.61	W	forests
Metolius4	44.43	N	121.59	W	forests
Metolius5	44.44	N	121.59	W	forests
Metolius6	44.45	N	121.56	W	forests
Metolius7	44.43	N	121.67	W	forests
Metolius8	44.45	N	121.67	W	forests
Metolius9	44.46	N	121.66	W	forests
Metoliusyoung	44.43	N	121.57	W	forests

MorganMonroe	39.32	N	86.42	W	forests
NAUCentennial	35.83	N	111.76	W	forests
NAUCentennialthinned	35.14	N	111.73	W	forests
Pasoh	2.98	N	102.3	E	forests
PrinceAlbertSSA(SOAS)	53.63	N	106.2	W	forests
SantiamPass	44.42	N	121.8	W	forests
Scio	44.68	N	122.6	W	forests
Takayama	36.1	N	137.41	E	forests
Tapajos67	2.81	S	54.95	W	forests
Thompsond131	55.88	N	98.33	W	forests
ThompsonNSA(NOBS)	55.9	N	98.47	W	forests
WalkerBranch	35.96	N	84.28	W	forests
Wet-114	50.45	N	11.45	E	forests
Wet-33	50.45	N	11.45	E	forests
Wet-67	50.45	N	11.45	E	forests
Wet-T-57	50.45	N	11.46	E	forests
WillowCreek	45.47	N	90.08	W	forests
WindRiver	45.82	N	121.95	W	forests

Table 2: Sites selected for the validation of ABP model simulations.

3.1.2. STATISTICAL METRICS

The performance of the models is evaluated by comparing the simulated values of ABP by the model with in-situ ABP values obtained from biomass database.

The between-sites differences in average annual ABP based on different ecosystems (spatial variation) were evaluated by linear correlation analysis. The effects of meteorological and climate conditions on ABP simulations were tested by the analysis of residuals. In addition, the effect of management and of biotic variables (such as vegetation type, plant diameter and plant height) were taken into account in evaluating the model performances.

CHAPTER 4 RESULTS OF THE VALIDATION AT GLOBAL SCALE

4.1. PERFORMED ACTIVITIES

In this session are reported the results of the first validation based on the modelled data for 2007 and 2008 years. We evaluated the model outputs provided by ICL over selected sites (see).

Results of the ABP validation at global scale are presented in sections from 4.2 to 4.5.

4.2. SPATIAL VARIATION ON ANNUAL ABP

Figure 1 reports the results of the the validation of in-situ observed and modelled spatial variation (among sites) in annual ABP.
Overall model simulation shows quite good performance in predicting ABP annual spatial variability when considering forest and grassland biomes together (R^2 = 0.32; *p* = <0.001; RMSE = 200.46 gC m^{-2} y^{-1}; bias = -28.62 gC m^{-2} y^{-1}). The model simulations tend to better estimate ABP of grasslands than forests (R^2 = 0.46; *p* = 0.007; RMSE = 123.97 gC m^{-2} y^{-1}; bias = -47.59 gC m^{-2} y^{-1}; and R^2 = 0.23; *p* = <0.001; RMSE = 222.00 gC m^{-2} y^{-1}; bias = -24.34 gC m^{-2} y^{-1}, respectively).

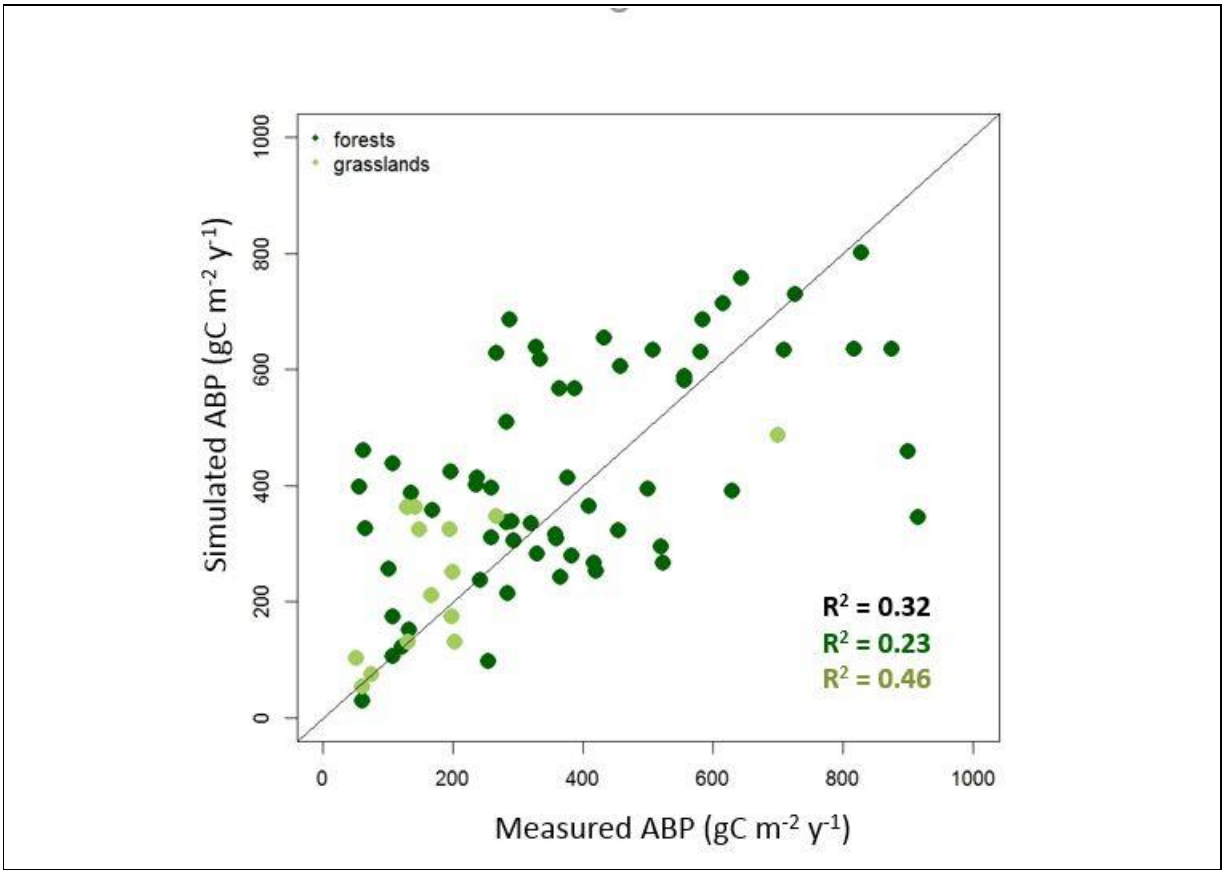

Figure 1: Comparison of in-situ observed and modelled spatial variations in annual ABP for forests (in dark green) and grasslands (in light green). Black line represents the linear correlation model for data

pooled by biomes. Correlation coefficients (cor) are given for all sites pooled together (in black), for forests (in dark green) and grasslands (in light green) separately.

4.3. IMPACT OF MANAGEMENT ON ABP

Figure 1 shows the analysis of residuals (the difference between simulated and measured data) for different types of management of forests (Fig. 3a: managemed, recented disturbed and unmanaged) and grasslands (Fig. 3b: natural (N) and semi-natural (SN)).

The model simulations predicted well the ABP of recently disturbed forests (R^2 = 0.93; RMSE = 177.74 gC m^{-2} y^{-1}; bias = 103.96 gC m^{-2} y^{-1} ; *p* = 0.04) while it tended to overestimate the ABP of managed forests (R^2 = 0.22; RMSE = 219.00 gC m^{-2} y^{-1}; bias = 59.26 gC m^{-2} y^{-1} ; *p* = 0.004) and underestimated ABP of managed forests (R^2 = 0.24; RMSE = 239.13 gC m^{-2} y^{-1}; bias = -69.19 gC m^{-2} y^{-1} ; *p* = 0.02). The model performed better for natural than semi natural grasslands (R^2 = 0.97; RMSE = 42 gC m^{-2} y^{-1}; bias = -26.64 gC m^{-2} y^{-1}; *p* = 0.10; and R^2 = 0.28; RMSE = 87.93 gC m^{-2} y^{-1}; bias = 59.80 gC m^{-2} y^{-1} ; *p* = 0.36; respectevly). However, it understimated the ABP of natural grasslands (bias = -26.64 gC m^{-2} y^{-1} ; *p* = 0.10) and overstimated the ABP of seminatural grasslands.

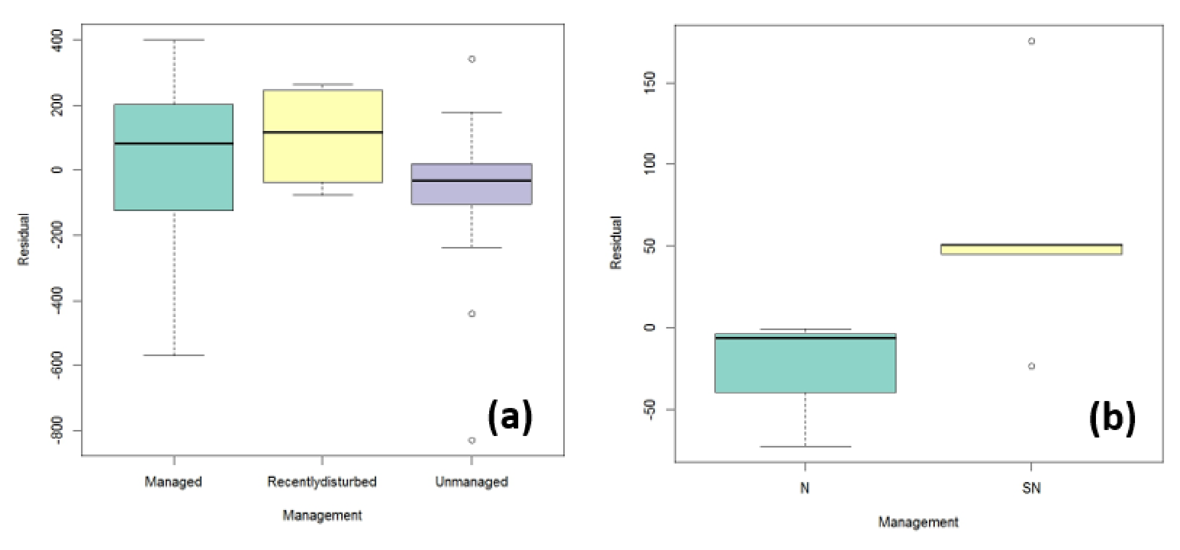

Figure 2: Boxplot of residuals (simulated – measured data) for ***(a)*** *forests and* ***(b)*** *grasslands management (N: natural; SN: semi natural).*

4.4. CONTROL OF METEOROLOGICAL VARIABLES ON ABP

Figure 1 and Figure 4 show the analysis of residuals (the difference between simulated and measured data) for different climate regions where are located forest and grassland sites, repectively. The models simulations underestimated the ABP for forest sites located in tropical humid and semiarid regions and sighly overestimated the ABP of forests in Meditarrenean region. The model tended to overestimate the ABP of grasslands in arid and temperate regions.

The effect of annual temperature on residuals was similar for both forests and grasslands. The annual precipitation had a quite large effect on large on residuals for forests while didn't have any effect on grassland ABP.

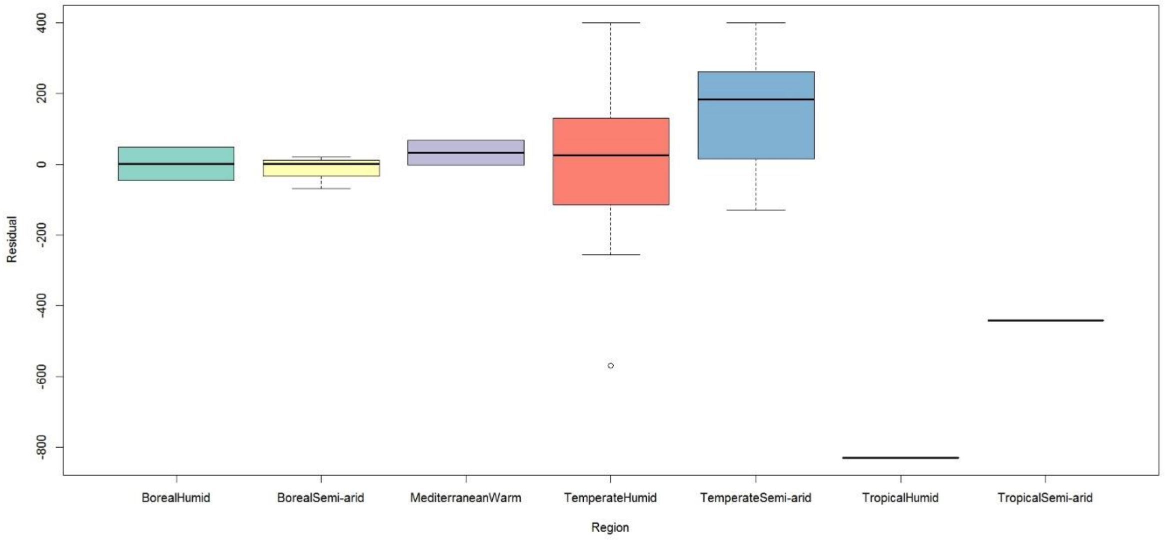

Figure 3: Boxplot of residuals (simulated – measured data) for forests for climate regions.

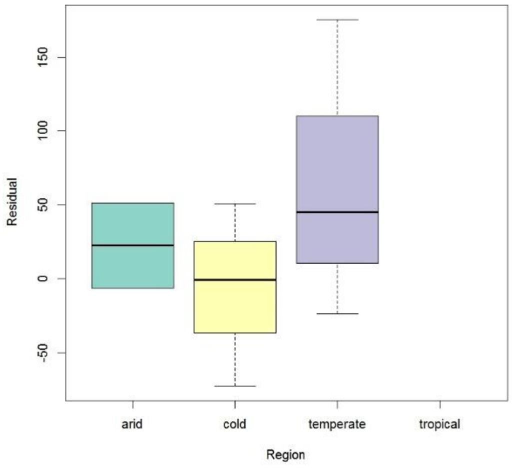

Figure 4: Boxplot of residuals (simulated – measured data) for grasslands for climate regions.

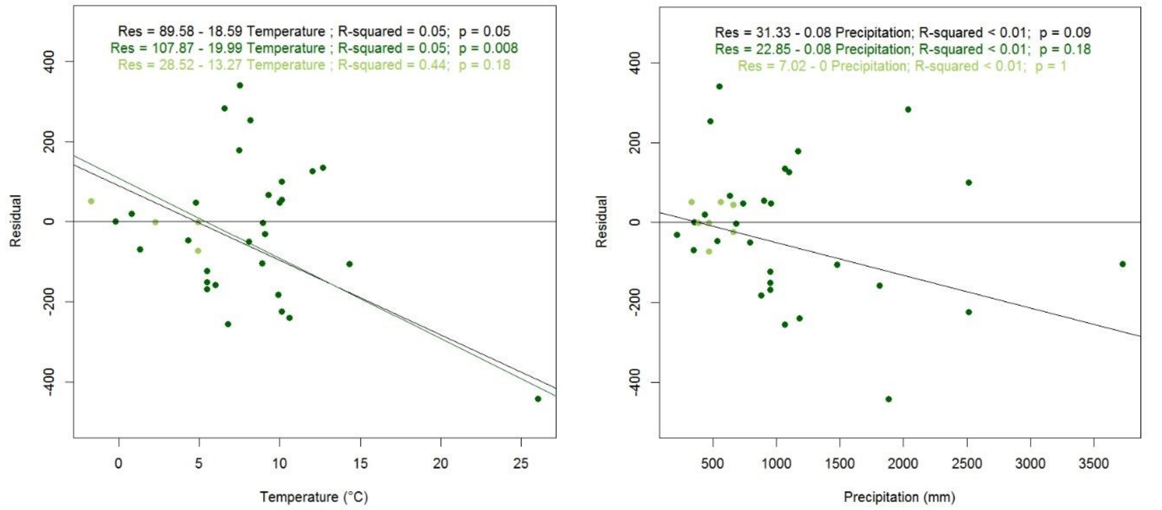

Figure 5: Plot of residuals against temperature (left panel) and precipitation (right panel) for forests (dark green) and grassalnds (light green).

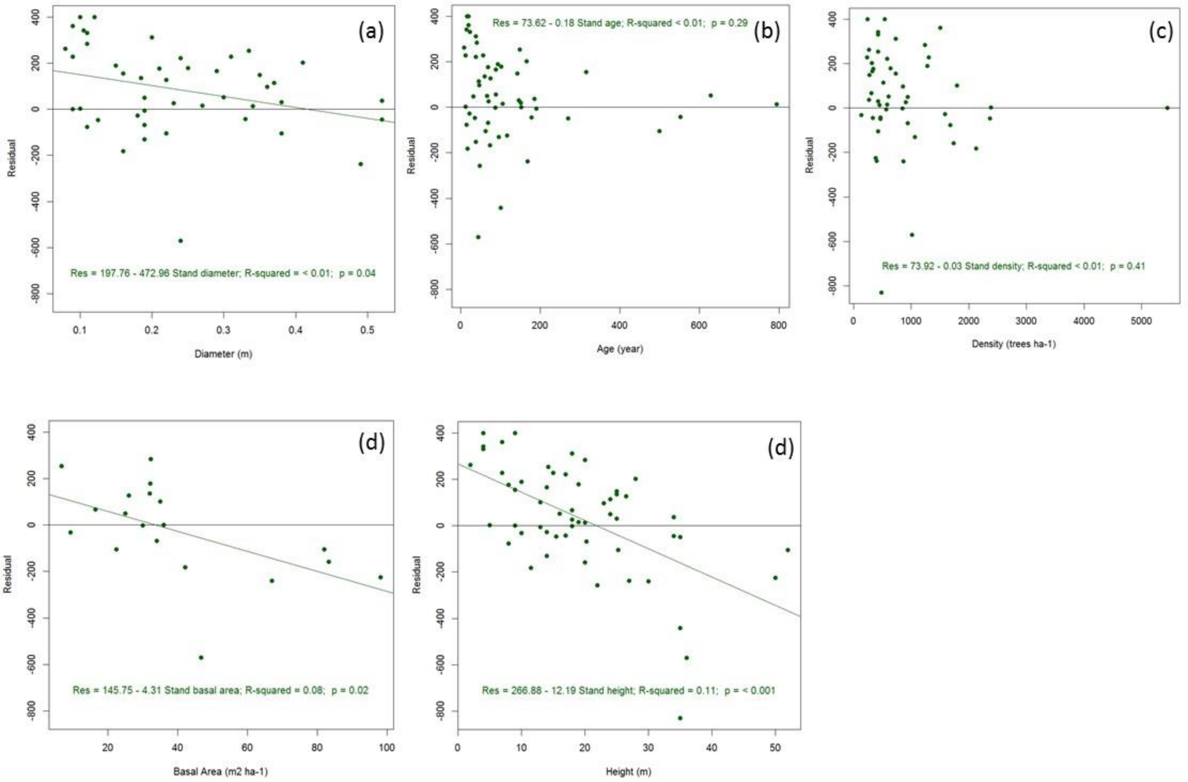

Figure 6: Plot of residuals for forests biometric variables: (a) diameter; (b) age; (c) density; (d) basal area and (e) height.

CHAPTER 5 CONCLUSIONS

5.1. GENERAL CONCLUSIONS

This report has evaluated the performance of the P model, as implemented in TerrA-P, by comparison with in-situ biometric measurements of ABP.

Comparisons of simulations and measurements have been made at the annual time scale, focusing on the model's ability to reproduce annual spatial variability of ABP.

The most important findings are as follows:

- Spatial patterns of annual ABP (represented by between-site differences) are reasonably well simulated for grasslands.
- The type of management had a significant effect on the simulation of ABP. The model simulations simulated well ABP for recently disturbed forests, but variation in goodness of predicitons was much larger for managed or unmanaged (natural) forests. The model p the ABP of semi natural grasslands.
- The annual temperature and precipitation regimes had an effect on model simulations of forests ABP. For grasslands only annual temperature showed an effect on simulated ABP.
- Biotic variables related to trees characteristics did effect the ABP simulations of forests.
- The climate region and forest type (evergreen and deciduous) had an important role in predicting ABP.

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