Měření úhlové distribuce listů v listnatých porostech za použití UAV

Jan Pisek — TARTU OBSERVATORY space research centre

Brenden McNeil — West Virginia University

Harald Lepisk — inspiratsioon.ee mõttelennu kaivitaja

20.dubna, 2016, MUNI Brno

Vzdělání

2004 Mgr. Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR
(vedoucí práce: Dr. Petr Dobrovolný)

2005 M.Sc. Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

2009 Ph.D. Physical Geography and Remote Sensing; University of Toronto, Kanada
(vedoucí práce: Dr. Jing Ming Chen)

Profesní dráha

2004-2009 Research Assistant, University of Toronto, Canada

2005 Visiting Scientist, Chinese Academy of Sciences, Beijing, China

2006-2009 Sessional Lecturer, University of Toronto, Toronto, Canada

2009-2010 Post-doctoral Research Fellow, Tartu Observatory, Estonia

2010-2013 Marie Curie Fellow, Tartu Observatory, Estonia

2013-2014 Visiting Scientist, Water Insight, B.V., The Netherlands

2014 - Senior Research Scientist, Tartu Observatory, Estonia

Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

Vzdělání

2004 Mgr. Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR
(vedoucí práce: Dr. Petr Dobrovolný)

2005 M.Sc. Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

2009 Ph.D. Physical Geography and Remote Sensing; University of Toronto, Kanada
(vedoucí práce: Dr. Jing Ming Chen)

Profesní dráha

2004-2009 Research Assistant, University of Toronto, Canada
2005 Visiting Scientist, Chinese Academy of Sciences, Beijing, China
2006-2009 Sessional Lecturer, University of Toronto, Toronto, Canada
2009-2010 Post-doctoral Research Fellow, Tartu Observatory, Estonia
2010-2013 Marie Curie Fellow, Tartu Observatory, Estonia
2013-2014 Visiting Scientist, Water Insight, B.V., The Netherlands
2014 - Senior Research Scientist, Tartu Observatory, Estonia

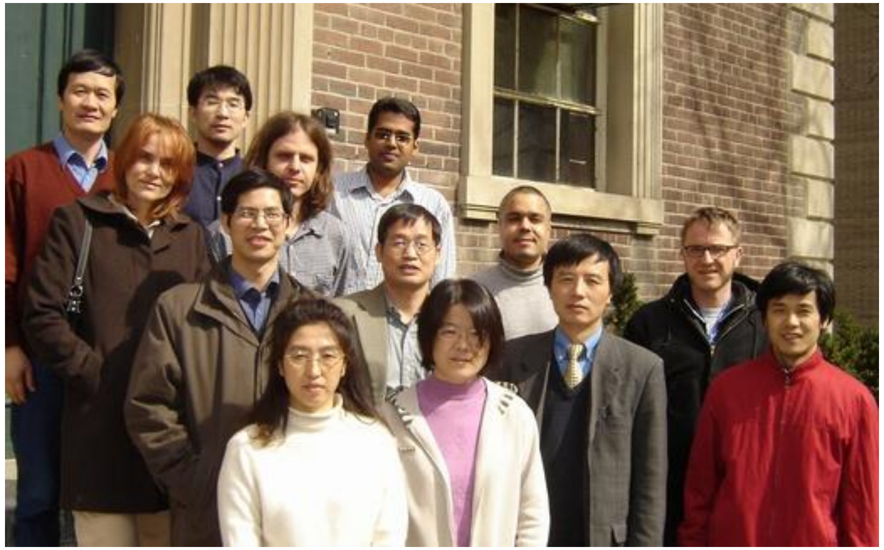
Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

Vzdělání

2004 Mgr. Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR
(vedoucí práce: Dr. Petr Dobrovolný)

2005 M.Sc. Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

2009 Ph.D. Physical Geography and Remote Sensing; University of Toronto, Kanada
(vedoucí práce: Dr. Jing Ming Chen)



Profesní dráha

2004-2009 Research Assistant, University of Toronto, Canada

2005 Visiting Scientist, Chinese Academy of Sciences, Beijing, China

2006-2009 Sessional Lecturer, University of Toronto, Toronto, Canada

2009-2010 Post-doctoral Research Fellow, Tartu Observatory, Estonia

2010-2013 Marie Curie Fellow, Tartu Observatory, Estonia

2013-2014 Visiting Scientist, Water Insight, B.V., The Netherlands

2014 - Senior Research Scientist, Tartu Observatory, Estonia

Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

Vzdělání

2004 Mgr. Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR (vedoucí práce: Dr. Petr Dobrovolný)

2005 M.Sc. Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

2009 Ph.D. Physical Geography and Remote Sensing; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

Profesní dráha

2004-2009 Research Assistant, University of Toronto, Canada

2005 Visiting Scientist, Chinese Academy of Sciences, Beijing, China

2006-2009 Sessional Lecturer, University of Toronto, Toronto, Canada

2009-2010 Post-doctoral Research Fellow, Tartu Observatory, Estonia

2010-2013 Marie Curie Fellow, Tartu Observatory, Estonia

2013-2014 Visiting Scientist, Water Insight, B.V., The Netherlands

2014 - Senior Research Scientist, Tartu Observatory, Estonia

Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

Vzdělání

2004 Mgr. Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR
(vedoucí práce: Dr. Petr Dobrovolný)

2005 M.Sc. Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

2009 Ph.D. Physical Geography and Remote Sensing; University of Toronto, Kanada
(vedoucí práce: Dr. Jing Ming Chen)

Profesní dráha

2004-2009 Research Assistant, University of Toronto, Canada

2005 Visiting Scientist, Chinese Academy of Sciences, Beijing, China

2006-2009 Sessional Lecturer, University of Toronto, Toronto, Canada

2009-2010 Post-doctoral Research Fellow, Tartu Observatory, Estonia

2010-2013 Marie Curie Fellow, Tartu Observatory, Estonia

2013-2014 Visiting Scientist, Water Insight, B.V., The Netherlands

2014 - Senior Research Scientist, Tartu Observatory, Estonia

Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

Vzdělání

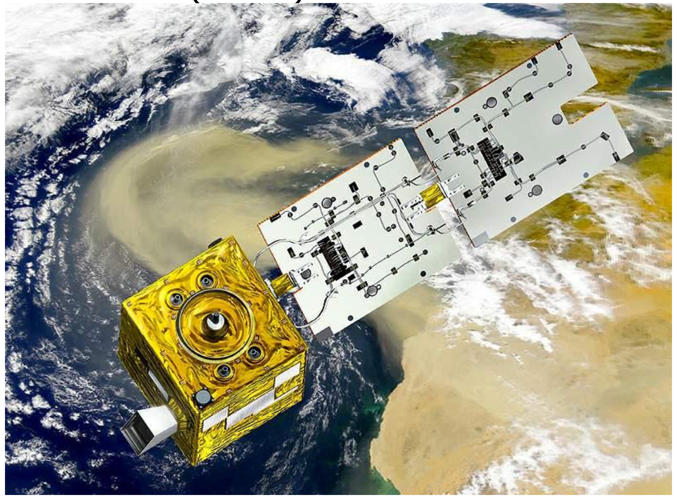
2004 Mgr.	Kartografie a geoinformatika; Masarykova Univerzita, Brno, ČR (vedoucí práce: Dr. Petr Dobrovolný)
2005 M.Sc.	Physical Geography; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)
2009 Ph.D.	Physical Geography and Remote Sensing; University of Toronto, Kanada (vedoucí práce: Dr. Jing Ming Chen)

Profesní dráha

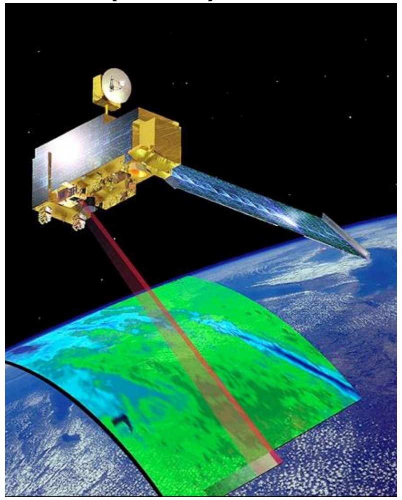
2004-2009	Research Assistant, University of Toronto, Canada
2005	Visiting Scientist, Chinese Academy of Sciences, Beijing, China
2006-2009	Sessional Lecturer, University of Toronto, Toronto, Canada
2009-2010	**Post-doctoral Research Fellow, Tartu Observatory, Estonia**
2010-2013	**Marie Curie Fellow, Tartu Observatory, Estonia**
2013-2014	Visiting Scientist, Water Insight, B.V., The Netherlands
2014 -	**Senior Research Scientist, Tartu Observatory, Estonia**

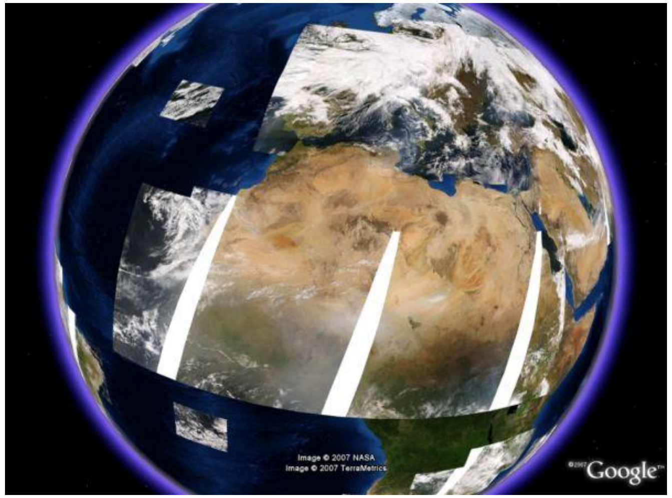
Zkoumání struktury vegetace pomocí in situ měření a DPZ (zaměření na využití víceúhlových měření)

POLDER 1-3 (~6 km)

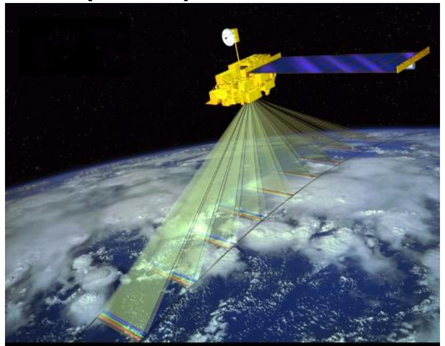


MODIS (500 m)

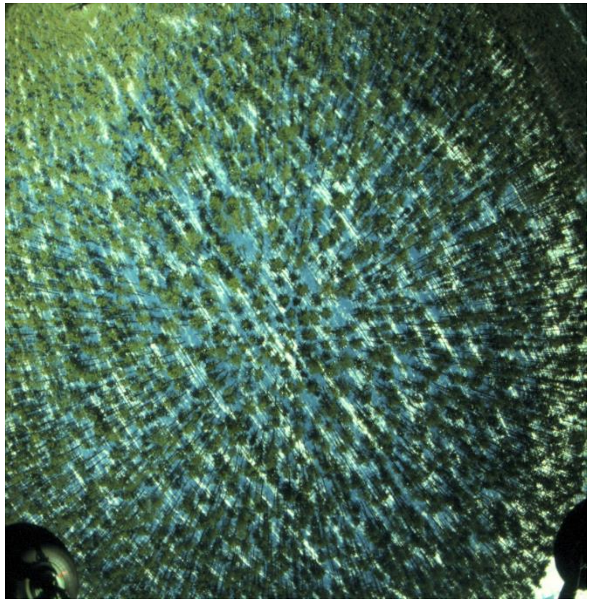


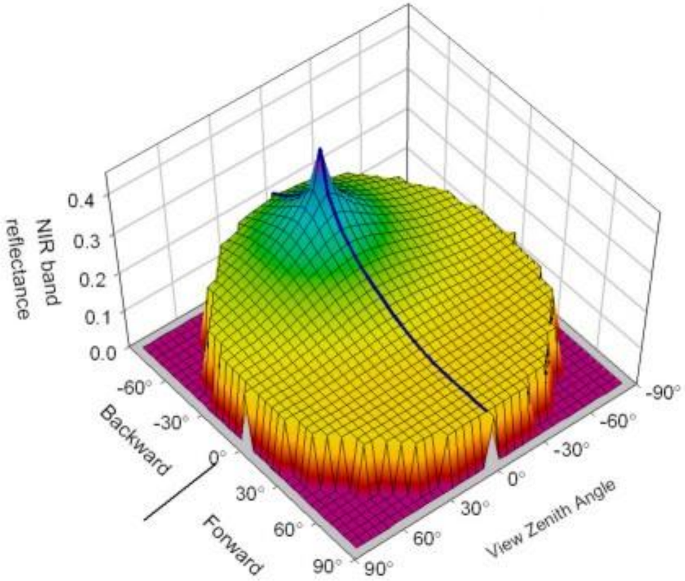


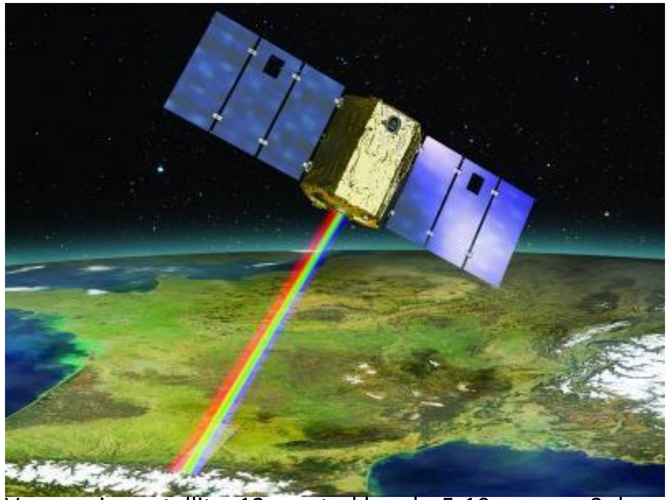
MISR (275 m)



MISR (Multi-angle Imaging Spectro-Radiometer) instrument on Terra satellite. MISR has nine cameras, each aimed at a different angle to get stereo information for every point on Earth.

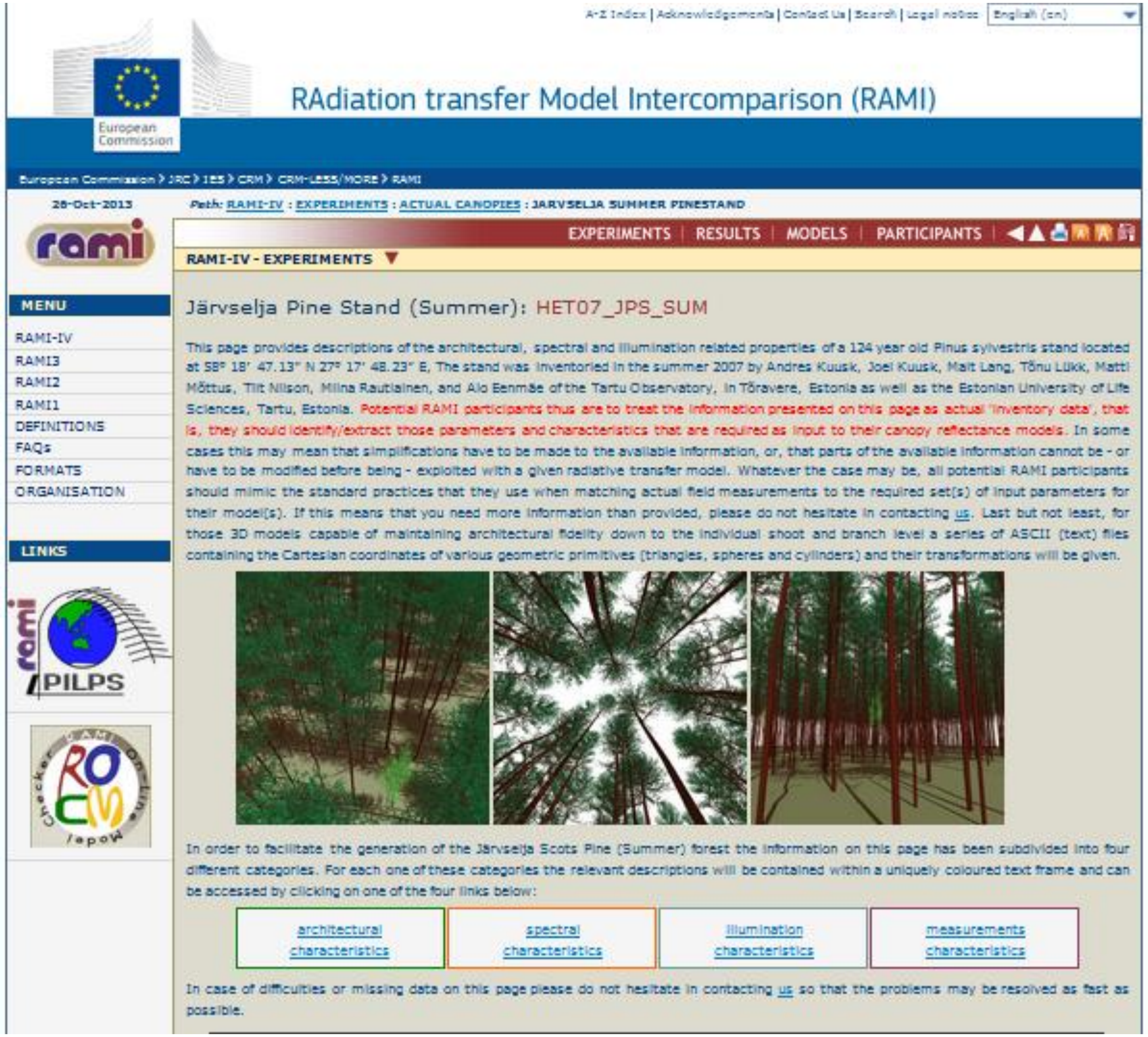




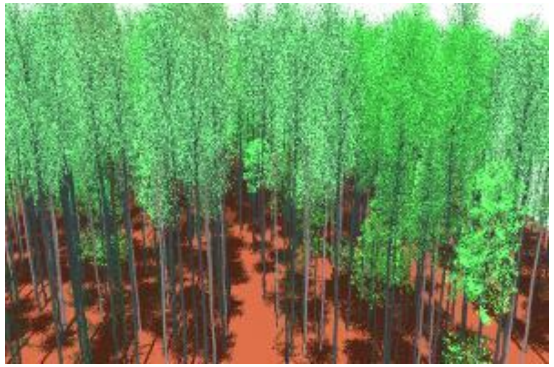


Venµs microsatellite, 12 spectral bands, 5-10 m every 2 days

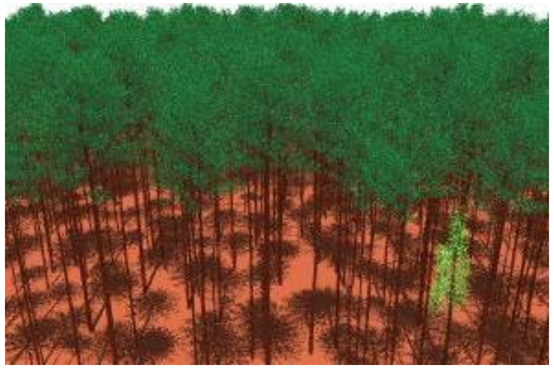
Järvselja RAMI testovací plochy

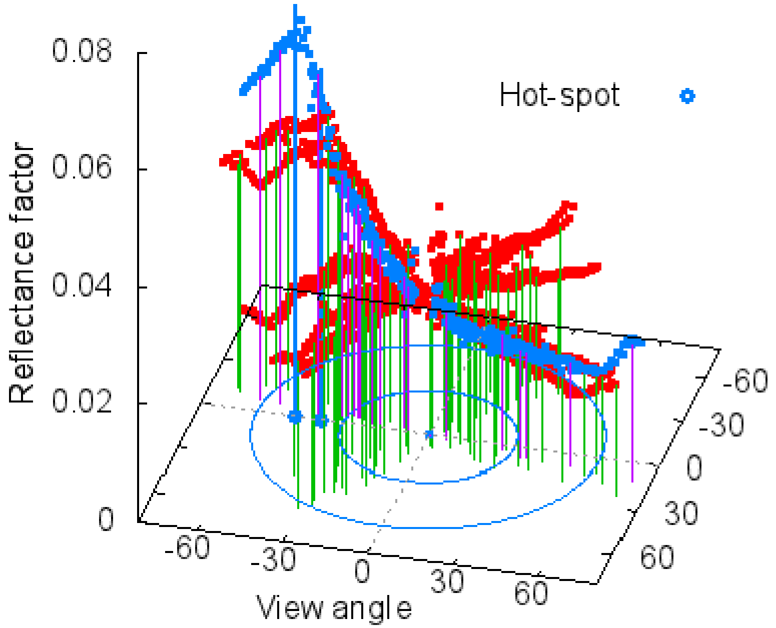


Bříza



Borovice





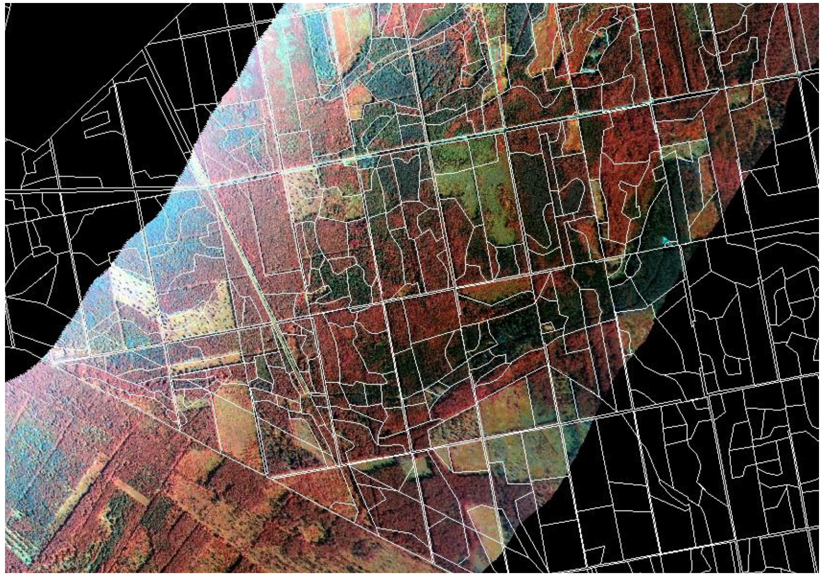


Foto: Joel Kuusk

Lightweight unmanned aerial vehicles will revolutionize spatial ecology

Karen Anderson* and Kevin J Gaston

Ecologists require spatially explicit data to relate structure to function. To date, heavy reliance has been placed on obtaining such data from remote-sensing instruments mounted on spacecraft or manned aircraft, although the spatial and temporal resolutions of the data are often not suited to local-scale ecological investigations. Recent technological innovations have led to an upsurge in the availability of unmanned aerial vehicles (UAVs) – aircraft remotely operated from the ground – and there are now many lightweight UAVs on offer at reasonable costs. Flying low and slow, UAVs offer ecologists new opportunities for scale-appropriate measurements of ecological phenomena. Equipped with capable sensors, UAVs can deliver fine spatial resolution data at temporal resolutions defined by the end user. Recent innovations in UAV platform design have been accompanied by improvements in navigation and the miniaturization of measurement technologies, allowing the study of individual organisms and their spatiotemporal dynamics at close range.

Front Ecol Environ 2013; 11(3): 138–146, doi:10.1890/120150 (published online 18 Mar 2013)

Remote-sensing techniques have transformed ecological research by providing both spatial and temporal perspectives on ecological phenomena that would otherwise be difficult to study (eg Kerr and Ostrovsky 2003; Running *et al*. 2004; Vierling *et al*. 2008). In particular, a strong focus has been placed on the use of data obtained from spaceborne remote-sensing instruments because these provide regional- to global-scale observations and repeat time-series sampling of ecological indicators (eg Gould 2000). The main limitation of most of the research-focused satellite missions is the mismatch between the pixel resolution of many regional-extent sensors (eg Landsat [spatial resolution of ~30 m] to the Moderate Resolution Imaging Spectro- range of new (largely commercially operated) satellite sensors have become operational over the past decade, offering data at finer than 10-m spatial resolution with more responsive capabilities (eg Quickbird, IKONOS, GeoEye-1, OrbView-3, WorldView-2). Such data are useful for ecological studies (Fretwell *et al*. 2012), but there remain three operational constraints: (1) a high cost per scene; (2) suitable repeat times are often only possible if oblique view angles are used, distorting geometric and radiometric pixel properties; and (3) cloud contamination, which can obscure features of interest (Loarie *et al*. 2007). Imaging sensors on board civilian aircraft platforms may also be used; these can provide more scale-appropriate data for

Měření úhlové distribuce listů v listnatých porostech za použití UAV

Jan Pisek TARTU OBSERVATORY space research centre

Brenden McNeil West Virginia University

Harald Lepisk inspiratsioon.ee mõttelennu käivitaja

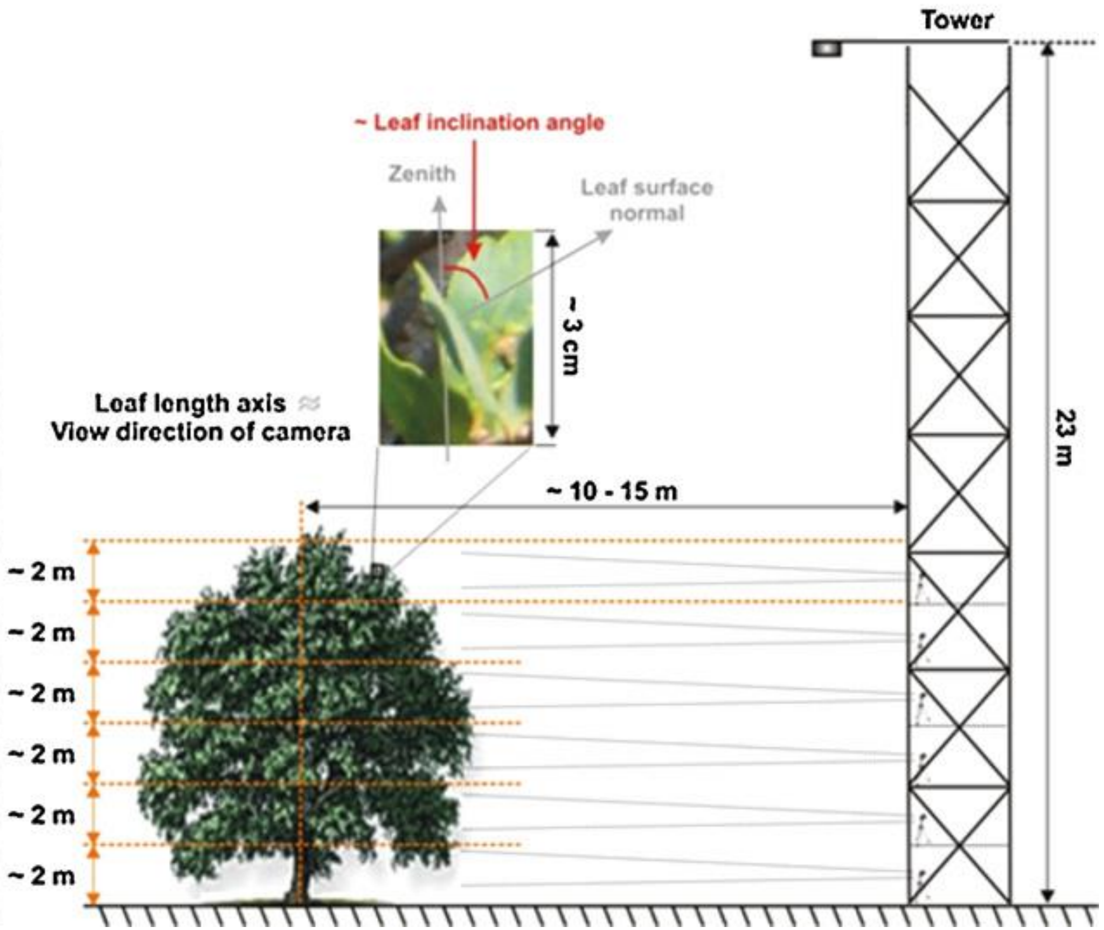
20.dubna, 2016, MUNI Brno

Listy

-rozdělení úhlů listoví (the leaf angle distribution - LAD) je jedním z hlavních parametrů ovlivňujících spektrální odrazivost a charakter šíření světla/záření skrz vegetaci

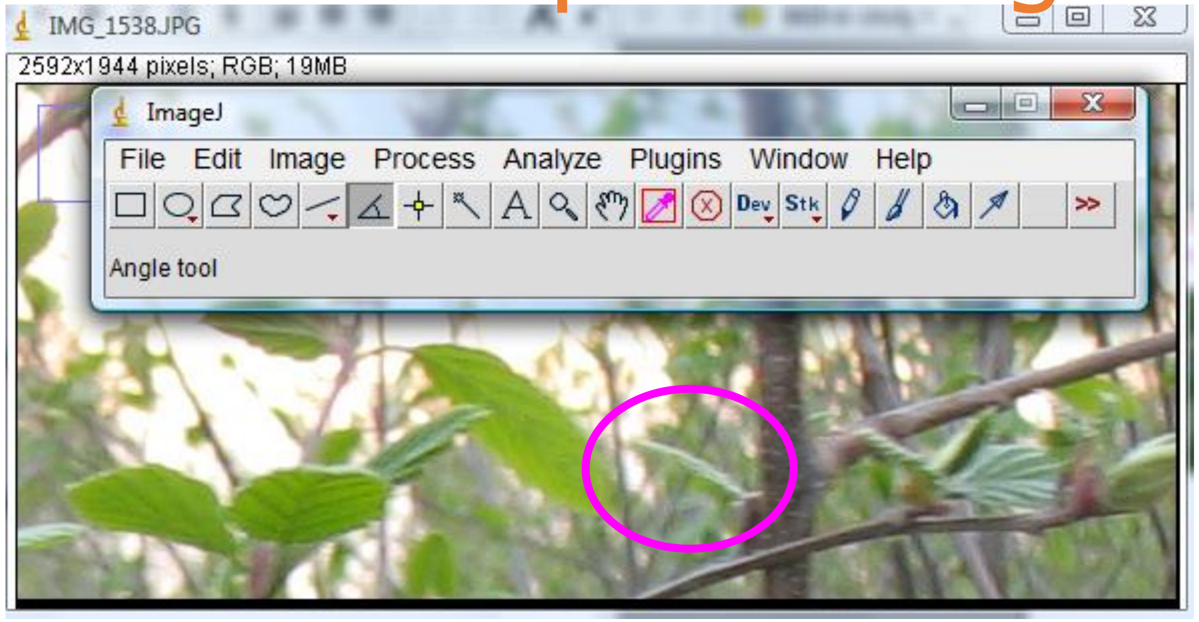
-navzdory svému významu ale zůstává jedním z nejméně prostudovanych parametrů/vstupů v modelech spektrální odrazivosti díky relativní obtížnosti měření úhlů listoví v terénu – obzvláště pak stromů

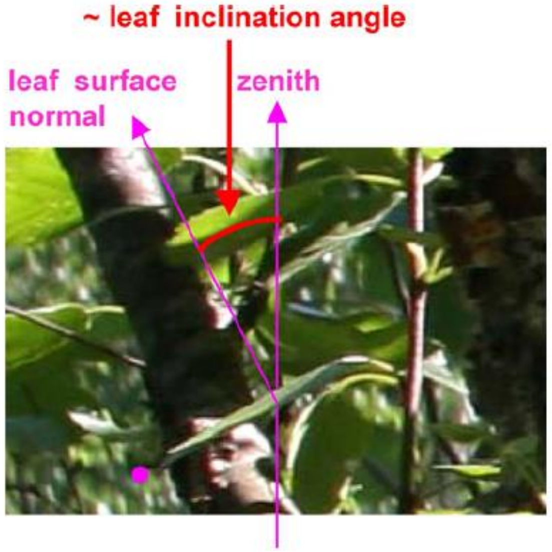
Měření pomocí dig. fotoaparátu (leveled digital camera approach)

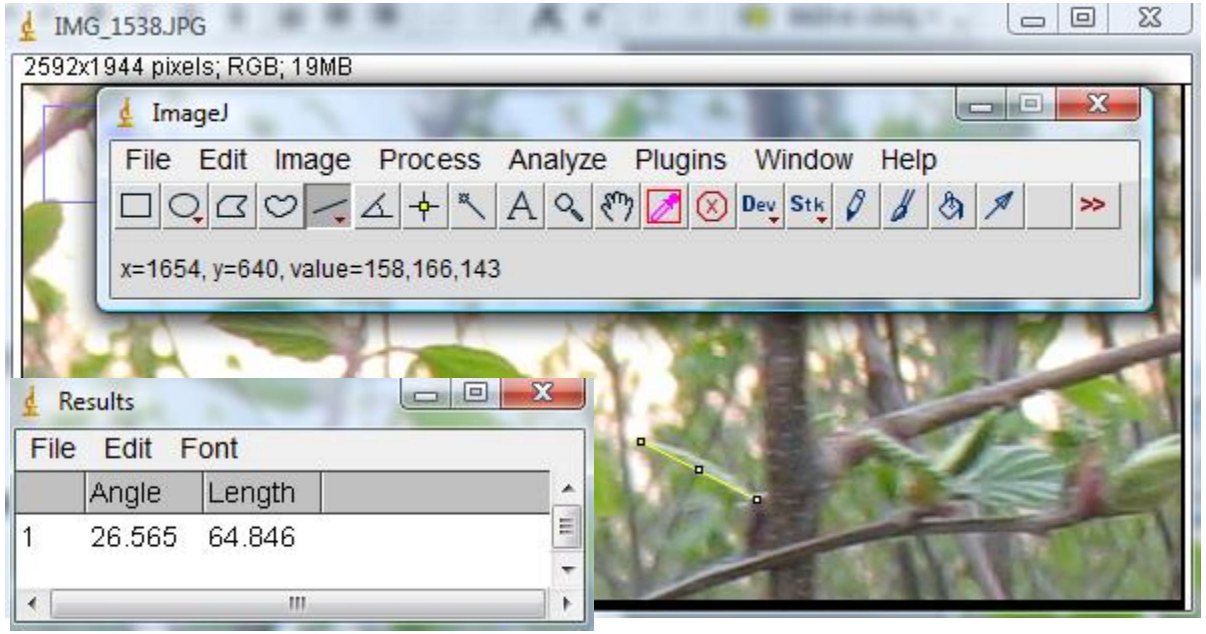


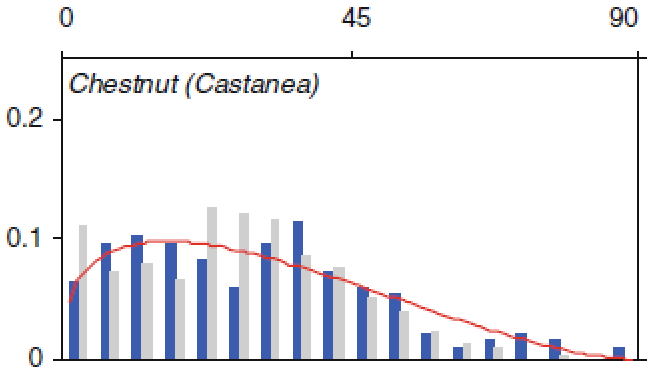
Ryu et al., 2010, AFM

Měření pomocí dig. fotoaparátu



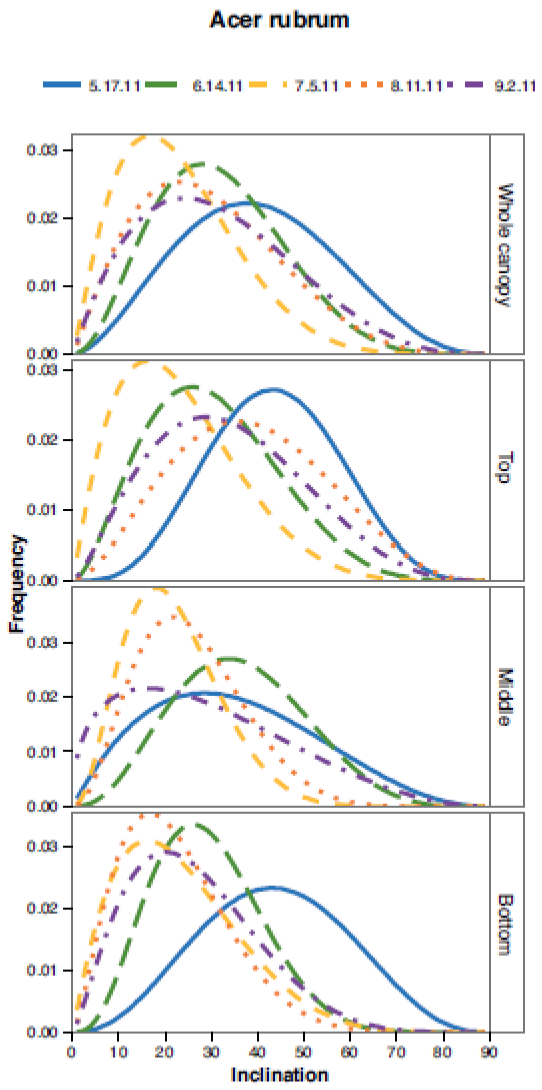






Ryu et al., 2010, AFM; Pisek et al., 2011, TREES, Pisek et al., 2013, AFM; Raabe et al., 2015, AFM

Je možné měřit úhly listoví kdykoliv/kdekoliv?

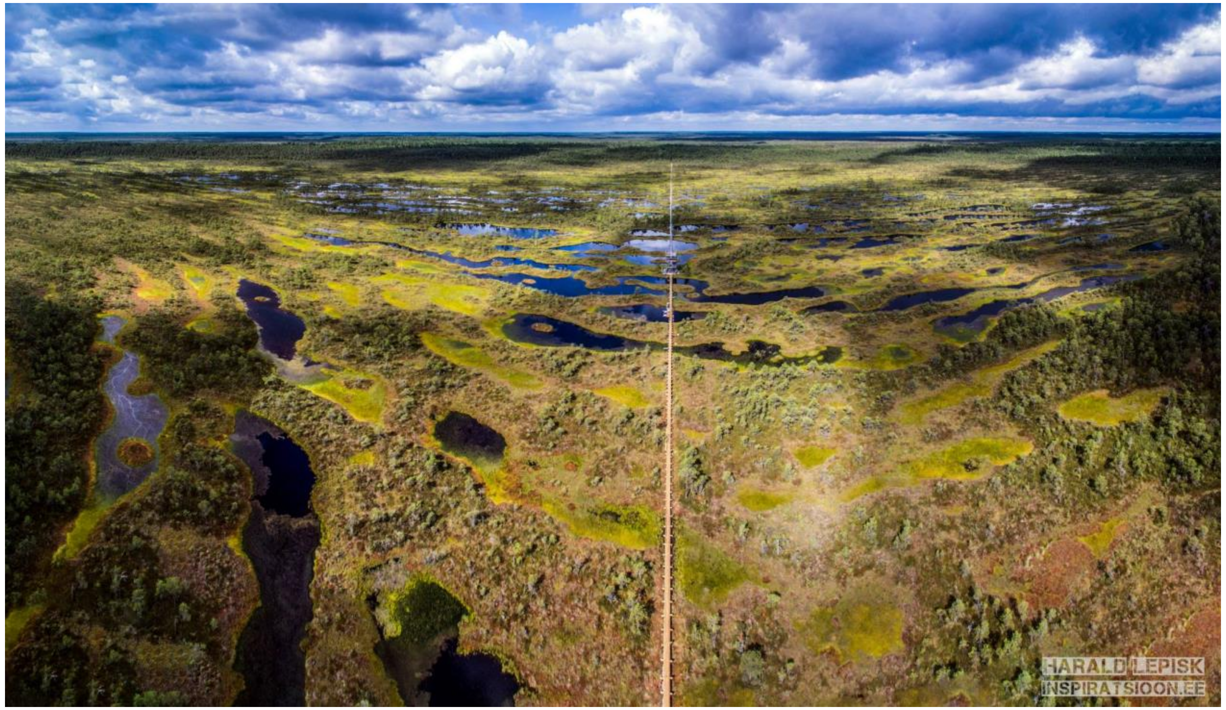


Raabe et al., 2015, AFM

Je možné měřit úhly listoví kdykoliv/kdekoliv?

DJI Phantom 3 Professional
4K camera with 3-axis gimbal
94 deg. recti-linear lens

Je možné měřit úhly listoví kdykoliv/kdekoliv?



30. června, 2015, Toravere, Estonsko
Betula pendula, Alnus incana, Aesculus hippocastanum

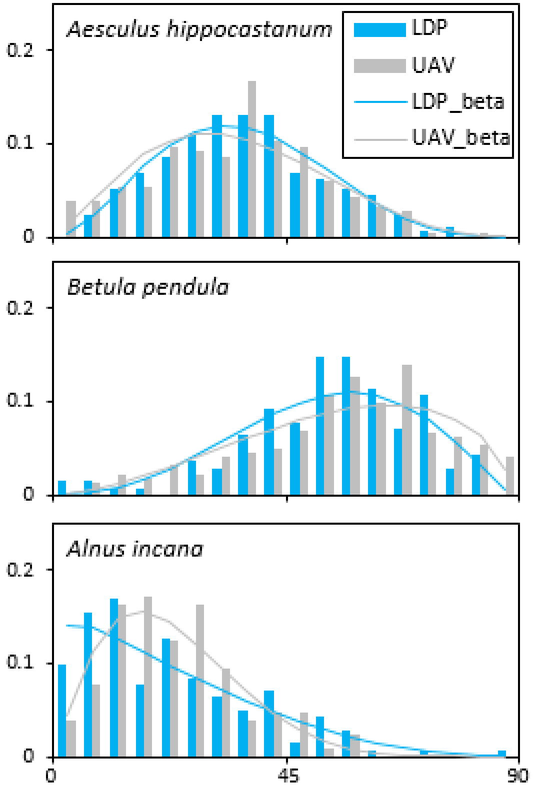


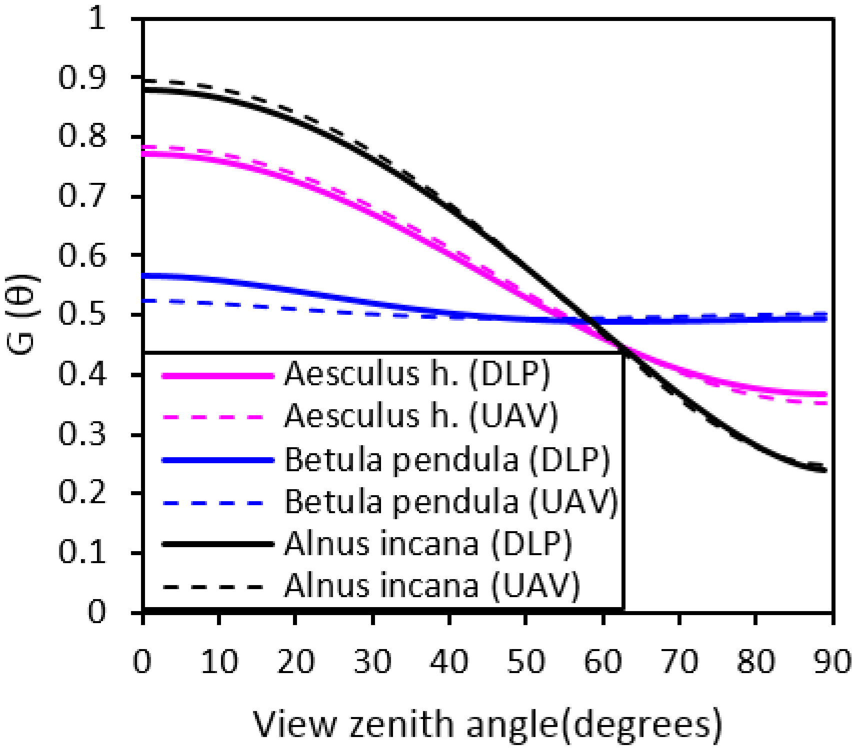
Původní RAW

Opravený JPEG (opravené prostorové zkreslení)

Výsledky

	control				UAV			
species	n	mean	standev	deWit	n	mean	standev	
Aesculus hippocastanum	175	36.91	15.22	plagiophile	186	35.28	16.34	plagiophile
Betula pendula	141	53.81	16.47	spherical	244	56.26	18.63	spherical
Alnus incana	142	22.98	17.04	planophile	128	23.48	12.67	planophile



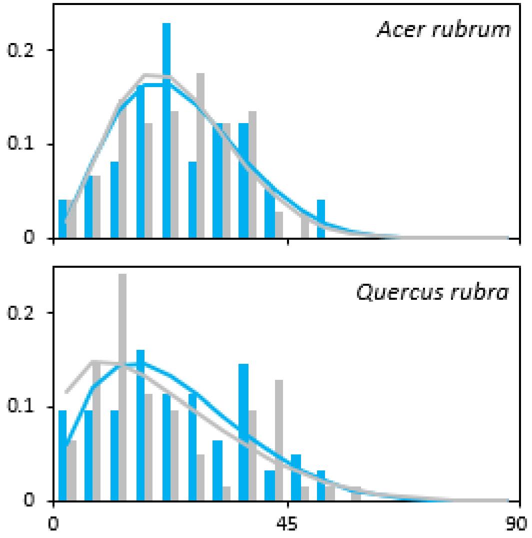


13. srpna, 2015, Monongahela National Forest, Central Appalachian Mountains, West Virginia, USA
Acer rubrum, Quercus rubra

3DRobotics Y6 hexacopter outfitted with a gimbal-mounted Canon Powershot S110 compact camera

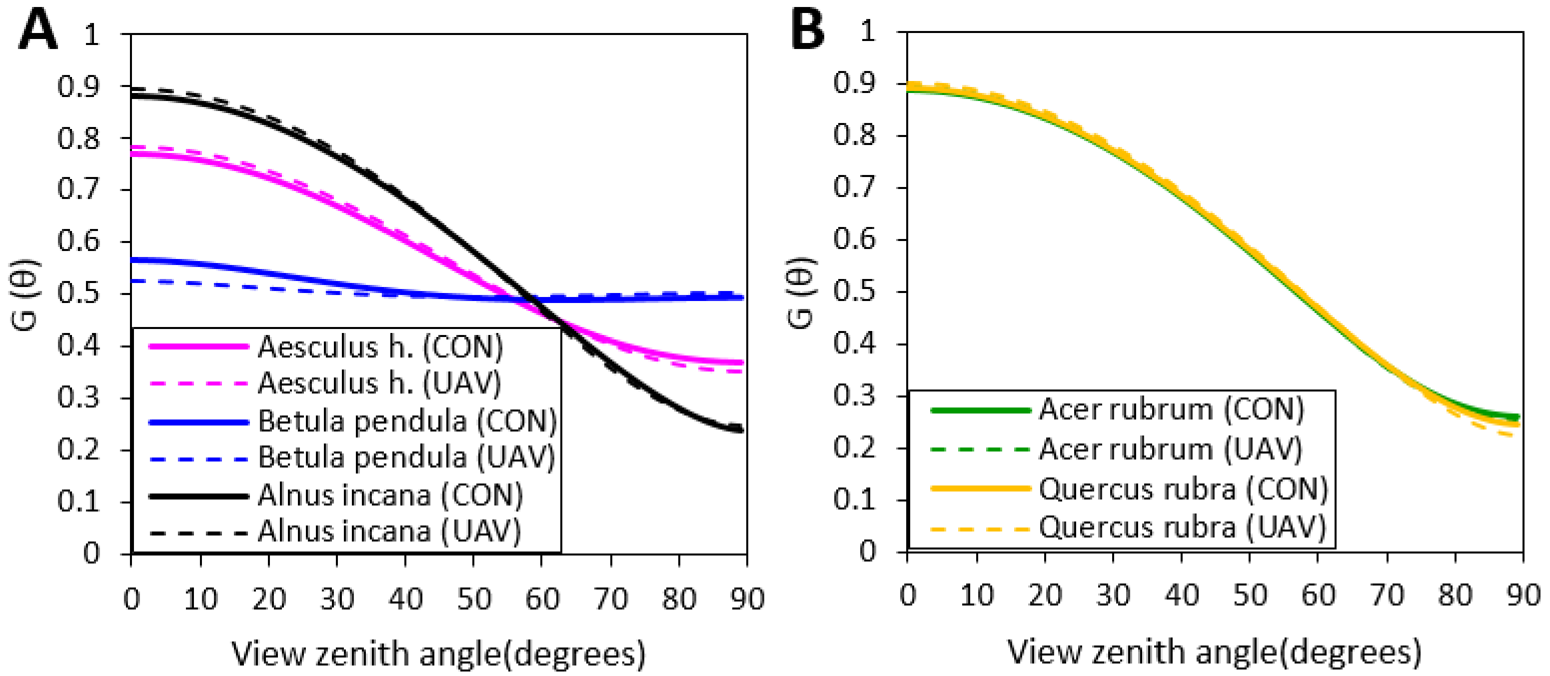
Výsledky

	control				UAV			
species	n	mean	standev	deWit	n	mean	standev	
Aesculus hippocastanum	175	36.91	15.22	plagiophile	186	35.28	16.34	plagiophile
Betula pendula	141	53.81	16.47	spherical	244	56.26	18.63	spherical
Alnus incana	142	22.98	17.04	planophile	128	23.48	12.67	planophile
Acer rubrum	74	24.81	11.76	planophile	74	24.15	11.06	planophile
Quercus rubra	62	23.56	13.66	planophile	62	21.87	14.45	planophile



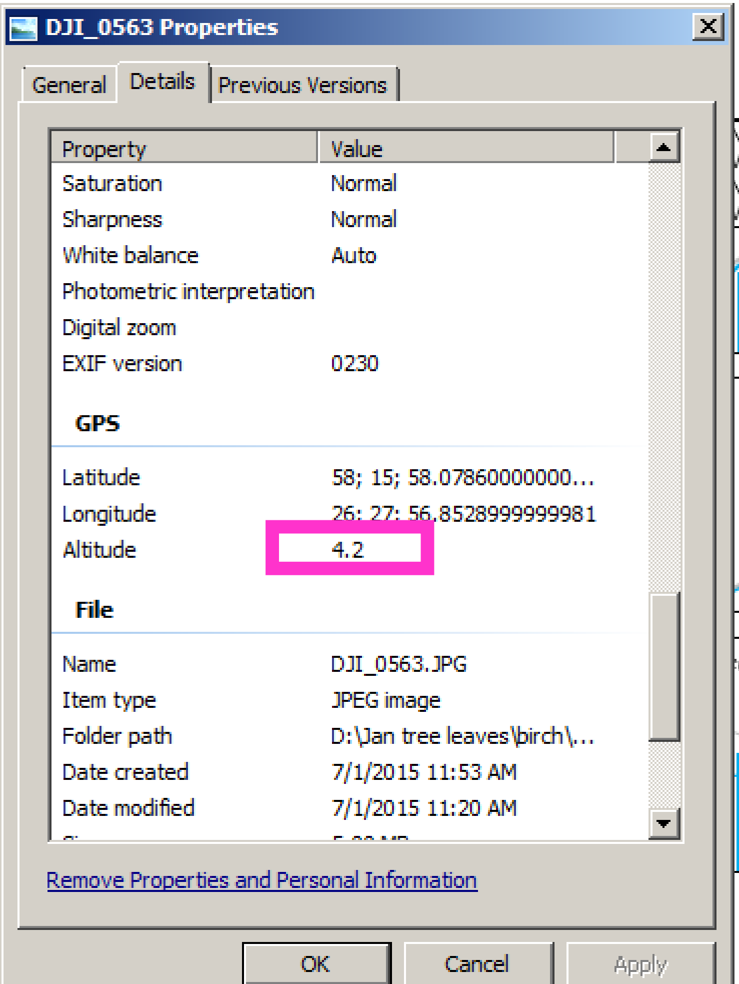
Výsledky

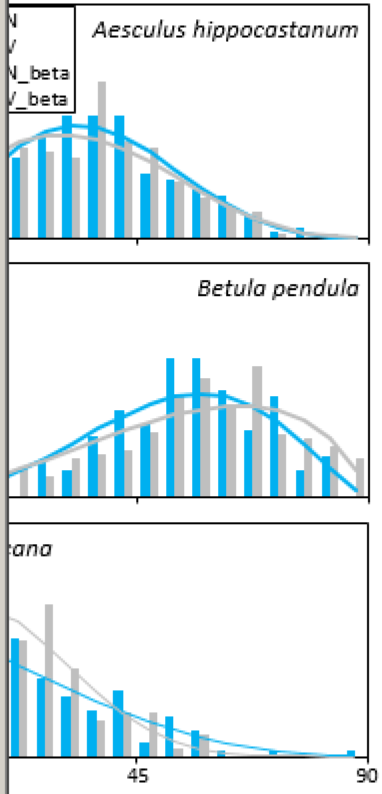
species	control				UAV			
	n	mean	standev	deWit	n	mean	standev	
Aesculus hippocastanum	175	36.91	15.22	plagiophile	186	35.28	16.34	plagiophile
Betula pendula	141	53.81	16.47	spherical	244	56.26	18.63	spherical
Alnus incana	142	22.98	17.04	planophile	128	23.48	12.67	planophile
Acer rubrum	74	24.81	11.76	planophile	74	24.15	11.06	planophile
Quercus rubra	62	23.56	13.66	planophile	62	21.87	14.45	planophile

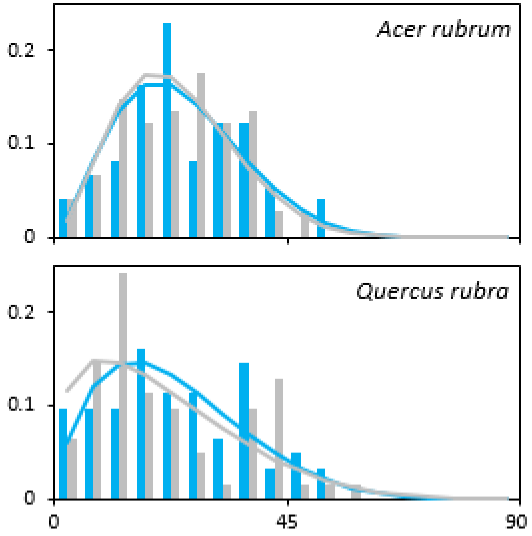


Výsledky

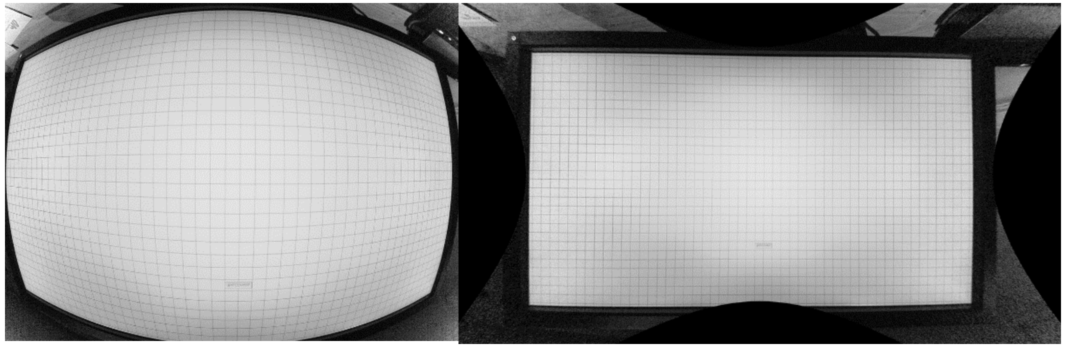
	control				UAV			
species	n	mean	standev	deWit	n	mean	standev	
Aesculus hippocastanum	175	36.91	15.22	plagiophile	186	35.28	16.34	plagiophile
Betula pendula	141	53.81	16.47	spherical	244	56.26	18.63	spherical
Alnus incana	142	22.98	17.04	planophile	128	23.48	12.67	planophile
Acer rubrum	74	24.81	11.76	planophile	74	24.15	11.06	planophile
	62	23.56	13.66	planophile	62	21.87	14.45	planophile



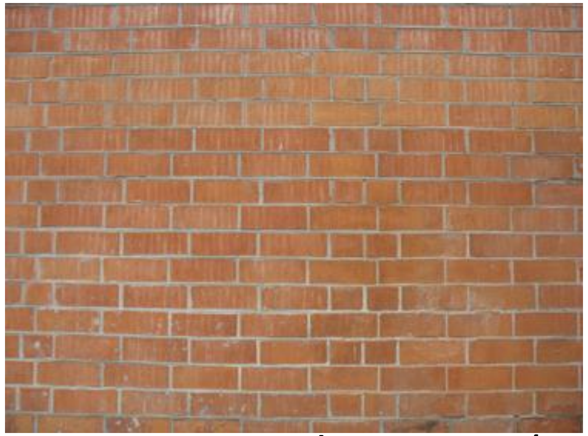




Na co dávat pozor?

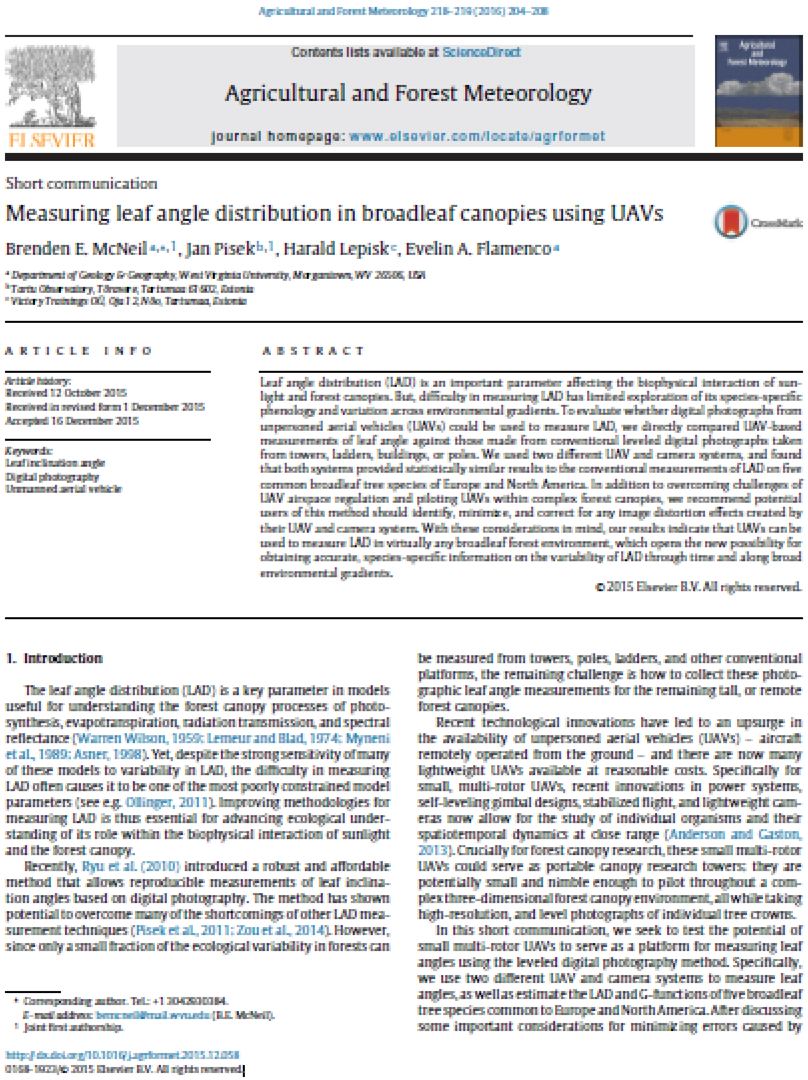


Kamera z GoPro Hero 2 UAV (zde nepoužita!)



Canon PowerShot A610 (použitý foťák pro ověření výsledků)

Jak dál?



Agricultural and Forest Meteorology 218–219 (2016) 204–208

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Short communication

Measuring leaf angle distribution in broadleaf canopies using UAVs

Brenden E. McNeil[a,*,1], Jan Pisek[b,1], Harald Lepisk[c], Evelin A. Flamenco[a]

[a] Department of Geology & Geography, West Virginia University, Morgantown, WV 26506, USA
[b] Tartu Observatory, Tõravere, Tartumaa 61602, Estonia
[c] Victory Trainings OÜ, Oja 1 2, Nõo, Tartumaa, Estonia

ARTICLE INFO

Article history:
Received 12 October 2015
Received in revised form 1 December 2015
Accepted 16 December 2015

Keywords:
Leaf inclination angle
Digital photography
Unmanned aerial vehicle

ABSTRACT

Leaf angle distribution (LAD) is an important parameter affecting the biophysical interaction of sunlight and forest canopies. But, difficulty in measuring LAD has limited exploration of its species-specific phenology and variation across environmental gradients. To evaluate whether digital photographs from unpersoned aerial vehicles (UAVs) could be used to measure LAD, we directly compared UAV-based measurements of leaf angle against those made from conventional leveled digital photographs taken from towers, ladders, buildings, or poles. We used two different UAV and camera systems, and found that both systems provided statistically similar results to the conventional measurements of LAD on five common broadleaf tree species of Europe and North America. In addition to overcoming challenges of UAV airspace regulation and piloting UAVs within complex forest canopies, we recommend potential users of this method should identify, minimize, and correct for any image distortion effects created by their UAV and camera system. With these considerations in mind, our results indicate that UAVs can be used to measure LAD in virtually any broadleaf forest environment, which opens the new possibility for obtaining accurate, species-specific information on the variability of LAD through time and along broad environmental gradients.

1. Introduction

The leaf angle distribution (LAD) is a key parameter in models useful for understanding the forest canopy processes of photosynthesis, evapotranspiration, radiation transmission, and spectral reflectance (Warren Wilson, 1959; Lemeur and Blad, 1974; Myneni et al., 1989; Asner, 1998). Yet, despite the strong sensitivity of many of these models to variability in LAD, the difficulty in measuring LAD often causes it to be one of the most poorly constrained model parameters (see e.g. Ollinger, 2011). Improving methodologies for measuring LAD is thus essential for advancing ecological understanding of its role within the biophysical interaction of sunlight and the forest canopy.

Recently, Ryu et al. (2010) introduced a robust and affordable method that allows reproducible measurements of leaf inclination angles based on digital photography. The method has shown potential to overcome many of the shortcomings of other LAD measurement techniques (Pisek et al., 2011; Zou et al., 2014). However, since only a small fraction of the ecological variability in forests can be measured from towers, poles, ladders, and other conventional platforms, the remaining challenge is how to collect these photographic leaf angle measurements for the remaining tall, or remote forest canopies.

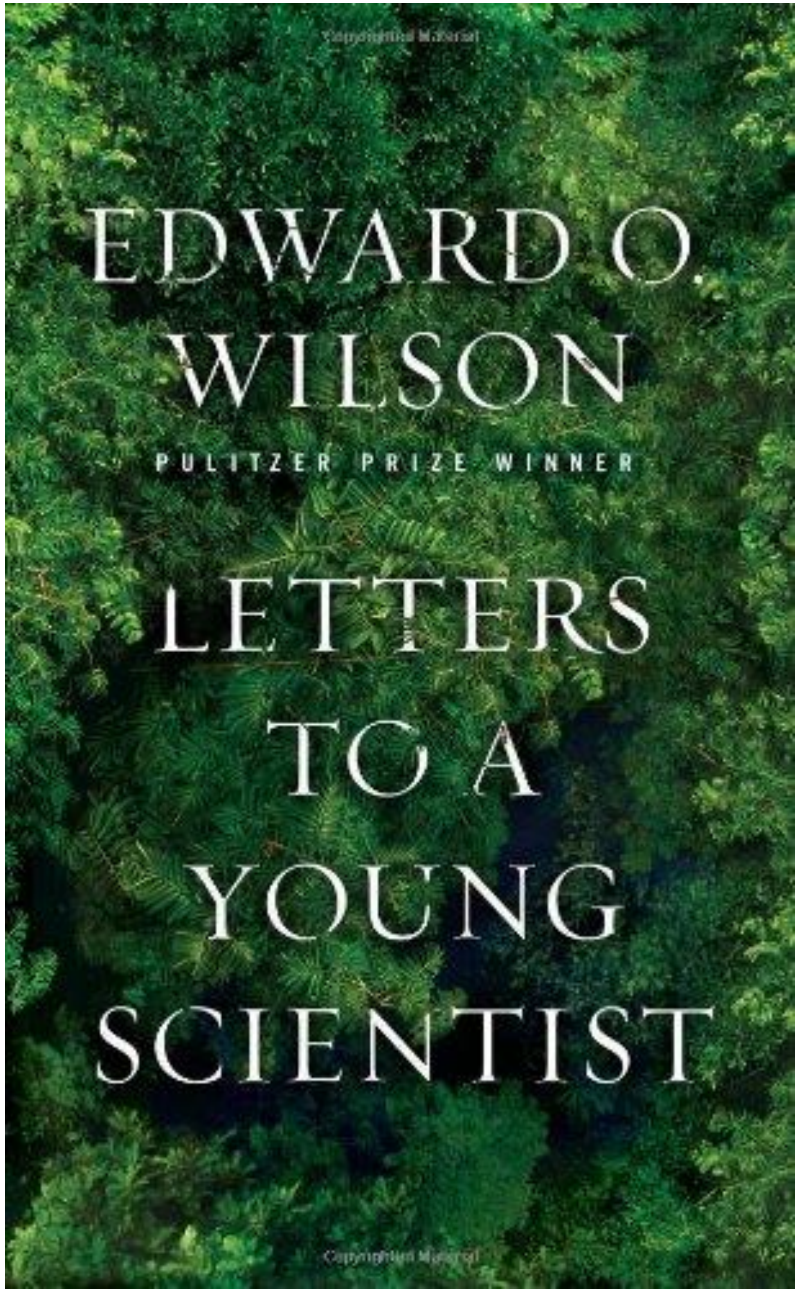
Recent technological innovations have led to an upsurge in the availability of unpersoned aerial vehicles (UAVs) – aircraft remotely operated from the ground – and there are now many lightweight UAVs available at reasonable costs. Specifically for small, multi-rotor UAVs, recent innovations in power systems, self-leveling gimbal designs, stabilized flight, and lightweight cameras now allow for the study of individual organisms and their spatiotemporal dynamics at close range (Anderson and Gaston, 2013). Crucially for forest canopy research, these small multi-rotor UAVs could serve as portable canopy research towers: they are potentially small and nimble enough to pilot throughout a complex three-dimensional forest canopy environment, all while taking high-resolution, and level photographs of individual tree crowns.

In this short communication, we seek to test the potential of small multi-rotor UAVs to serve as a platform for measuring leaf angles using the leveled digital photography method. Specifically, we use two different UAV and camera systems to measure leaf angles, as well as estimate the LAD and G-functions of five broadleaf tree species common to Europe and North America. After discussing some important considerations for minimizing errors caused by

* Corresponding author. Tel.: +1 3042930384.
E-mail address: bemcneil@mail.wvu.edu (B.E. McNeil).
[1] Joint first authorship.

http://dx.doi.org/10.1016/j.agrformet.2015.12.058

-automatizace identifikace listů a měření úhlů
-jehličnany?


EDWARD O.
WILSON
PULITZER PRIZE WINNER
LETTERS
TO A
YOUNG
SCIENTIST

Vedoucí práce

Hlavní je zápal/nadšení, až pak je kvalifikace/inteligence

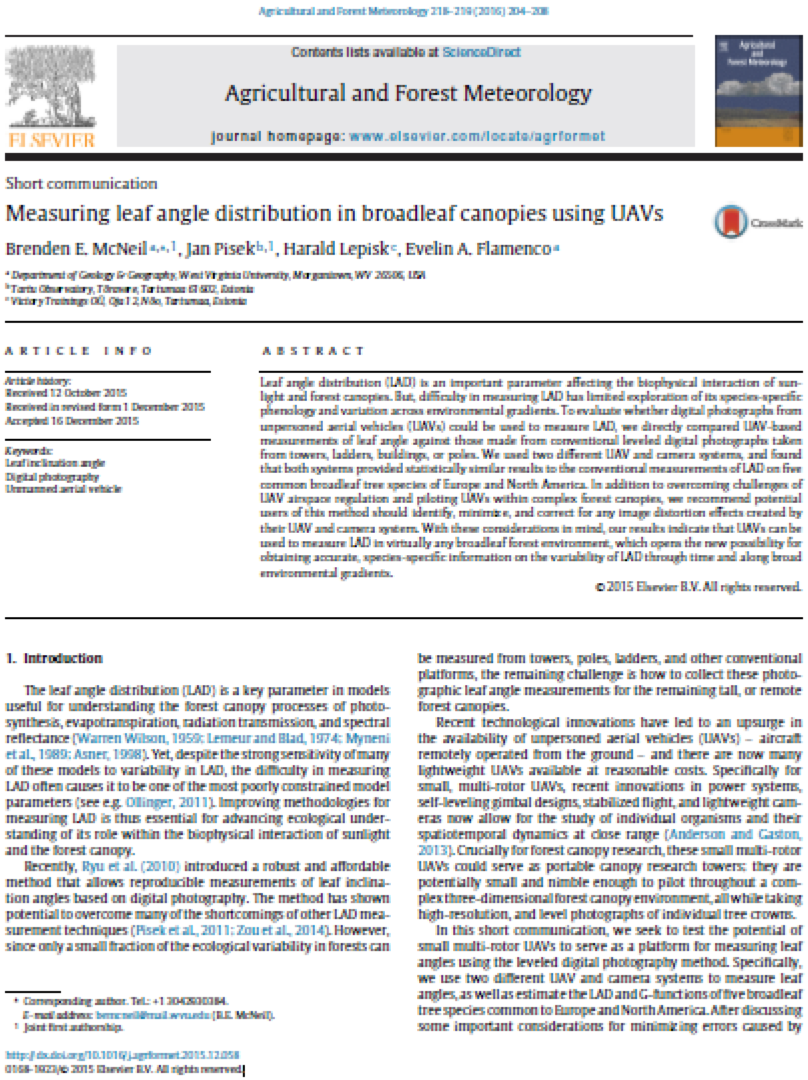
Too many Ph.D.s are creatively stillborn, with their personal research ending more or less with their doctoral dissertations.

Very often ambition and entrepreneurial drive, in combination, beat brilliance.

Zkoušejte stále něco nového

Disturb Nature and see if she reveals a secret.

Almost anything, no matter how unsophisticated, can yield discoveries publishable in scientific journals.



Agricultural and Forest Meteorology 218–219 (2016) 204–208

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Short communication

Measuring leaf angle distribution in broadleaf canopies using UAVs

Brenden E. McNeil[a,*,1], Jan Pisek[b,1], Harald Lepisk[c], Evelin A. Flamenco[a]

[a] Department of Geology & Geography, West Virginia University, Morgantown, WV 26506, USA
[b] Tartu Observatory, Tõravere, Tartumaa 61602, Estonia
[c] Victory Trainings OÜ, Oja 1 2, Nõo, Tartumaa, Estonia

ARTICLE INFO

Article history:
Received 12 October 2015
Received in revised form 1 December 2015
Accepted 16 December 2015

Keywords:
Leaf inclination angle
Digital photography
Unmanned aerial vehicle

ABSTRACT

Leaf angle distribution (LAD) is an important parameter affecting the biophysical interaction of sunlight and forest canopies. But, difficulty in measuring LAD has limited exploration of its species-specific phenology and variation across environmental gradients. To evaluate whether digital photographs from unpersoned aerial vehicles (UAVs) could be used to measure LAD, we directly compared UAV-based measurements of leaf angle against those made from conventional leveled digital photographs taken from towers, ladders, buildings, or poles. We used two different UAV and camera systems, and found that both systems provided statistically similar results to the conventional measurements of LAD on five common broadleaf tree species of Europe and North America. In addition to overcoming challenges of UAV airspace regulation and piloting UAVs within complex forest canopies, we recommend potential users of this method should identify, minimize, and correct for any image distortion effects created by their UAV and camera system. With these considerations in mind, our results indicate that UAVs can be used to measure LAD in virtually any broadleaf forest environment, which opens the new possibility for obtaining accurate, species-specific information on the variability of LAD through time and along broad environmental gradients.

1. Introduction

The leaf angle distribution (LAD) is a key parameter in models useful for understanding the forest canopy processes of photosynthesis, evapotranspiration, radiation transmission, and spectral reflectance (Warren Wilson, 1959; Lemeur and Blad, 1974; Myneni et al., 1989; Asner, 1998). Yet, despite the strong sensitivity of many of these models to variability in LAD, the difficulty in measuring LAD often causes it to be one of the most poorly constrained model parameters (see e.g. Ollinger, 2011). Improving methodologies for measuring LAD is thus essential for advancing ecological understanding of its role within the biophysical interaction of sunlight and the forest canopy.

Recently, Ryu et al. (2010) introduced a robust and affordable method that allows reproducible measurements of leaf inclination angles based on digital photography. The method has shown potential to overcome many of the shortcomings of other LAD measurement techniques (Pisek et al., 2011; Zou et al., 2014). However, since only a small fraction of the ecological variability in forests can be measured from towers, poles, ladders, and other conventional platforms, the remaining challenge is how to collect these photographic leaf angle measurements for the remaining tall, or remote forest canopies.

Recent technological innovations have led to an upsurge in the availability of unpersoned aerial vehicles (UAVs) – aircraft remotely operated from the ground – and there are now many lightweight UAVs available at reasonable costs. Specifically for small, multi-rotor UAVs, recent innovations in power systems, self-leveling gimbal designs, stabilized flight, and lightweight cameras now allow for the study of individual organisms and their spatiotemporal dynamics at close range (Anderson and Gaston, 2013). Crucially for forest canopy research, these small multi-rotor UAVs could serve as portable canopy research towers; they are potentially small and nimble enough to pilot throughout a complex three-dimensional forest canopy environment, all while taking high-resolution, and level photographs of individual tree crowns.

In this short communication, we seek to test the potential of small multi-rotor UAVs to serve as a platform for measuring leaf angles using the leveled digital photography method. Specifically, we use two different UAV and camera systems to measure leaf angles, as well as estimate the LAD and G-functions of five broadleaf tree species common to Europe and North America. After discussing some important considerations for minimizing errors caused by

* Corresponding author. Tel.: +1 3042930384.
E-mail address: bemcneil@mail.wvu.edu (B.E. McNeil).
[1] Joint first authorship.

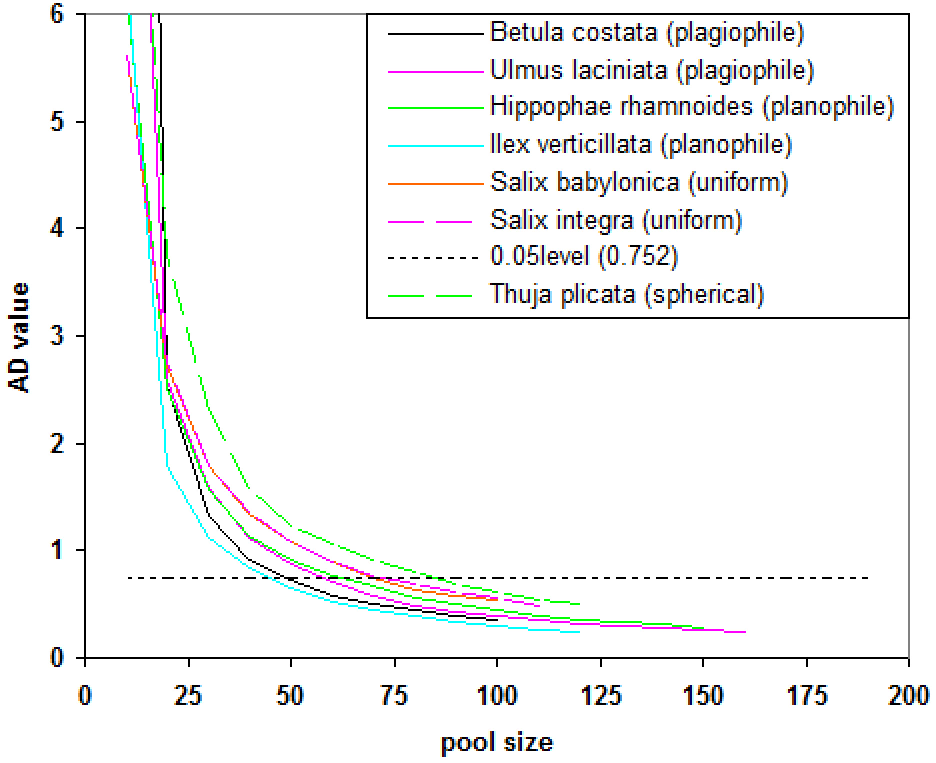
http://dx.doi.org/10.1016/j.agrformet.2015.12.058
0168-1923/

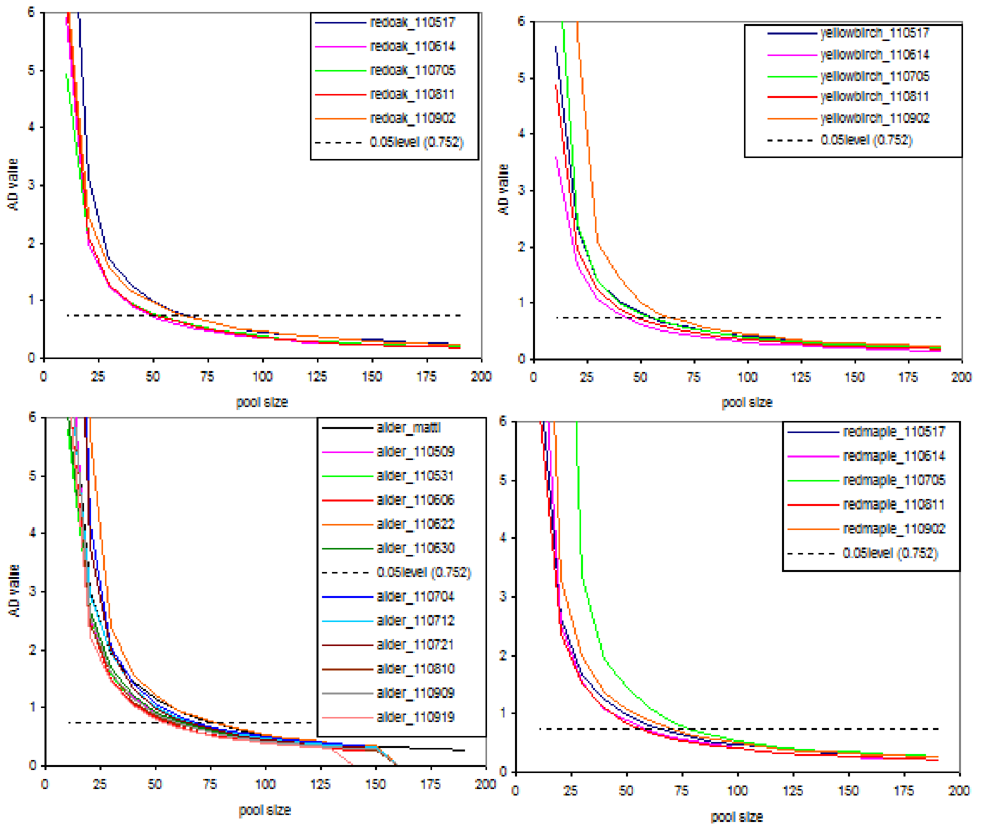
Mějte za kamaráda/kamarádku matematika/statistika

It is far easier for scientists to acquire needed collaboration from mathematicians and statisticians than it is for mathematicians and statisticians to find scientists able to make use of their equations.

For every scientist, whether researcher, technologist, or teacher, of whatever competence in mathematics, there exists a discipline in science for which that level of mathematical competence is enough to achieve excellence.

How many leaves are enough?





Anderson-Darling test (Anderson and Darling, 1952)

- test statistic of the sum of squares of the differences between the distribution of sample and a given probability distribution function, with a weight function that emphasizes discrepancies in both tails

Poznejte svůj obor/téma do poslední mrtě

Fortune favours **only** the prepared mind. Louis Pasteur, 1854

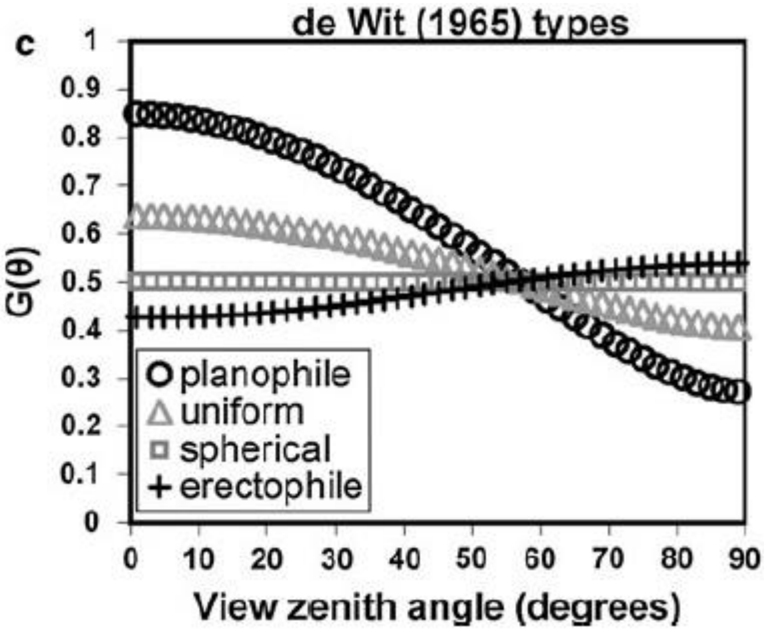
Na konci své dizertace by jste o daném tématu měli vědět více, než Váš vedoucí práce.

Využijte čas, dokud nemáte děti… ;)

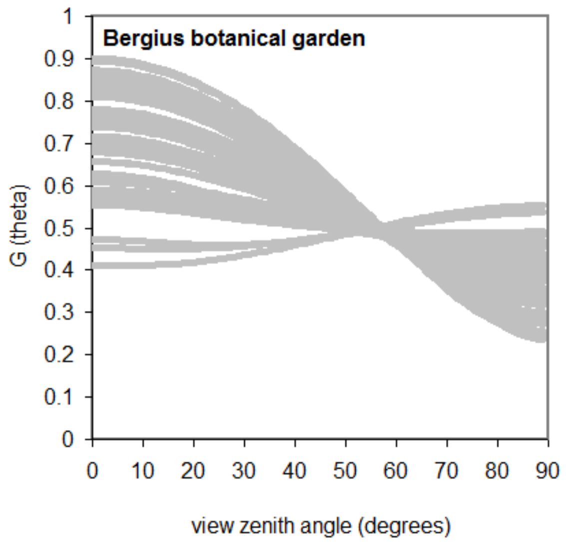
Zajímejte se o to, co zrovna není populární

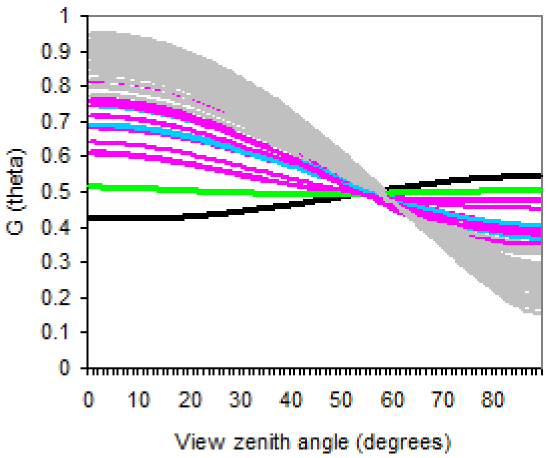
March away from the sound of the guns. Observe the fray from the distance, and while you are at it, consider making your own fray.

In the search for scientific discoveries, every problem is an opportunity. The more difficult the problem, the greater the likely importance of its solution.



$$P(\theta) = e^{-G(\theta)L\Omega/\cos\theta}$$



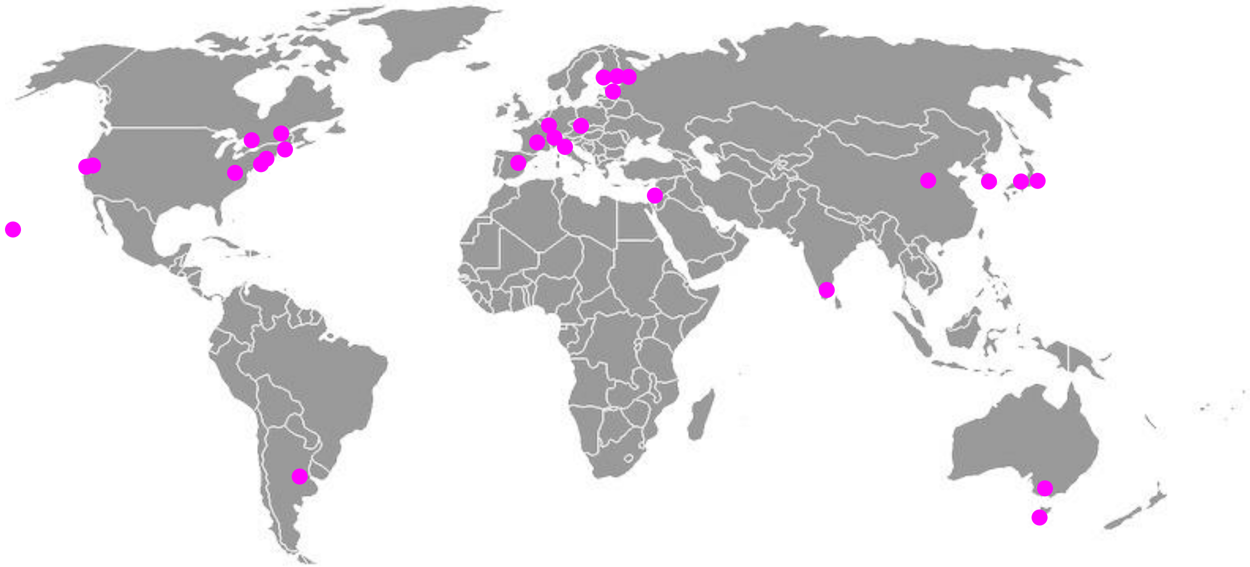


Nikdy si neberte "dovolenou"

Real scientist takes field trips or temporary research fellowships at other institutions.

Avoid department-level administration and duties as much as possible.

Asistujte, spolupracujte, tvořte, inovujte



University of Hawai'i, HI, USA
San Francisco State University, CA, USA
University of California, Berkeley, CA, USA
Boston University, MA, USA
Princeton University, NJ, USA
Montclair State University, NJ, USA
West Virginia University, WV, USA
University of Toronto, Canada
Université du Montréal, Canada
Universidad de Lujan, Argentina

Joint Research Centre, Italy
INRA, France
University of Zurich, Switzerland
CzechGlobe, Czech rep.
University of Valencia, Spain
University of Helsinki, Finland
Aalto University, Finland
University of Eastern Finland, Finland
Ben-Gurion University of the Negev, Israel

Seoul National University, Korea
JAMSTEC, Japan
Chiba University, Japan
Chinese Academy of Sciences, China
University of Kerala, India
University of Melbourne, Australia
Forestry Tasmania, Australia

Závist a nejistota patří mezi hlavní motory vědeckého pokroku

It won’t hurt if you have a dose of them also.

Etika ve vědě

Čím více budete citovat jiné, tím větsi je šance, že někdo bude citovat také Vás.