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农作物遥感识别是地理学和生态学研究的前沿和热点，多源数据在农作遥感识别中日益发挥重要作用。笔者从多源数据融合的角度，归纳了2000年后多源数据在农作物遥感识别中应用的总体概况，系统梳理并提炼了当前多源数据融合的主要融合技术和融合模式。围绕与多源数据融合和农作物遥感识别相关的关键词，在Google学术、ISI Web of Knowledge 和中国知网中对2000—2014年间国内外发表的论文进行检索，并统计不同传感器的使用频率及结合方式。研究表明，以提高空间分辨率为目标的多源数据融合和以提高时间分辨率为目标的多源数据融合技术是当前的两种主要方式，可以在一定程度上实现时空尺度的扩展。前者的融合技术包括图像融合、正态模糊分布神经网络模型、成分替换、半经验数据模型融合及多分辨率小波分解等，可以提升遥感数据的空间分解力和清晰度，较好弱化混合像元产生的影响，但农作物光谱信息有一定程度的丢失或扭曲，农作物空间分布局部细节信息与纹理特征依然会缺失；后者的融合技术形式灵活多样，可分为同源数据联合扩展时序的时空优化技术和异源数据联合扩展时序的时空优化技术，其可以有效排除短时间段内农作物生育期交叉，但易受不同遥感数据源间光谱反射率或植被指数转换模型及光谱波段设置差异的影响。在融合模式方面，根据数据类型分为光学数据的融合、光学数据与微波数据的融合以及遥感与非遥感数据的融合，以实现卫星资源优势互补为宗旨，充分挖掘不同类型农作物在遥感数据上呈现的光谱、时间和空间特征差异信息。同样，农作物遥感识别研究中的多源遥感数据融合也存在诸多挑战，在未来一段时间内，完善不同传感器之间的合作、更深层次挖掘融合信息以及多尺度长时间序列的中高分辨率农作物空间分布数据集的需求是多源数据融合的农作物遥感识别研究的重点发展方向和亟待解决的问题。研究结果有助于更好地理解多源遥感数据融合的技术和模式，为摸清多源数据融合在农作物识别中总体进展提供支撑，同时也为其他多源数据融合研究提供借鉴。

农作物；多源数据；融合；遥感；识别

Recent Progresses in Research of Integrating Multi-Source Remote Sensing Data for Crop Mapping

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Abstract: Crop mapping by using the remotely-sensed images provide basic information for further geographical and ecological researches. A systematic review on the recent literature regarding crop mapping was carried out in order to improve our understanding on the integration and application of multi-source remote sensing data. The literature search was performed in Google Scholar, the ISI Web of Knowledge and CNKI (e.g. Topic =”crop + mapping”; Topic =”classification + multi-source”; timespan =

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2000-2014). According to the thorough analysis on the existing publications, it is suggested that (1) there are two main ways to identify crop types based on the integration of multi-source data in order to expand the spatial and temporal scales. The techniques of multi-source data fusion, which are aimed at improving the spatial resolution, include image fusion, normal fuzzy distributed neural networks, component substitution, semi-physical fusion approach, and multiresolution wavelet decomposition. With the integrated application of such approaches, the spatial resolution and clarity of remote sensing images are raised; the effect of mixed pixels is weaken to some extent. Nevertheless, crop spectral information is partly lost or distorted. The techniques of multi-source data fusion, which are aimed at improving the temporal resolution, can be categorized into two types: the integration of the same data source, and the integration of different data sources. By using such approaches, the crossover of growth period among different crops can be effectively eliminated. But such approaches are susceptible to transformation models of spectral reflectance or vegetation indices, and the differences in band coverage among different remote sensing data. (2) The modes of multi-source data fusion can be categorized into three types according to the data types applied: integration of optical data, integration of optical and microwave data, and integration of remote sensing and ancillary data sources. Taking complementary advantages of various satellite data resources, these techniques of data fusion fully mine the differences of spectral, temporal and spatial characteristics, among various crop species. However, there still remain challenges in previous researches about the crop identification based on the fusion of multi-source remotely sensed data.

Key words: crop; multi-source; combining; remote sensing; identification

[1-2]

[3-4]

[5-6]

[7]

Puredue

Landsat TM[8-9]

MODIS[10-11] QuickBird[12]

[13]

[14]

[15]

[16-17]

/ / / Crop

Classification Mapping Google

ISI Web of Knowledge 2000—2014

297

1 “ ”

10

“ ”

“ ”

3

1

MODIS

34.7% Landsat

TM/ETM+ 35.0%

[18-21] 2

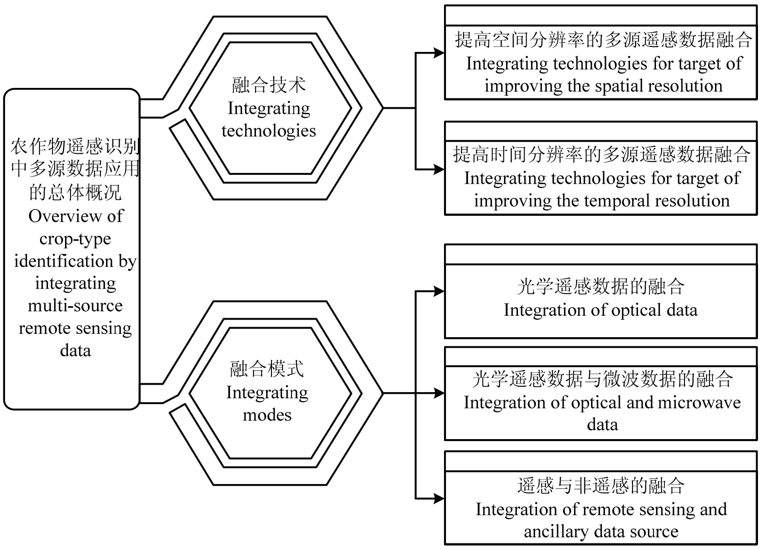
SAR

10.1%[22-23]

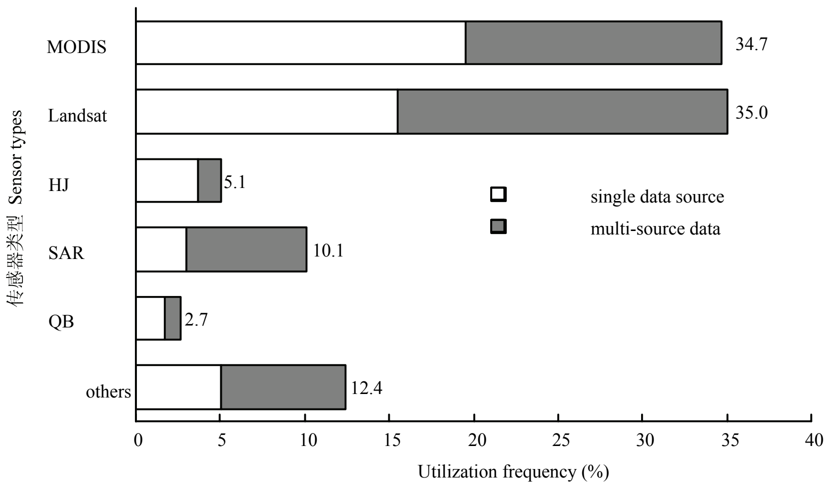
HJ-1A /1B

5.1%
[24] 189
QuickBird 108
15.1%
SAR
QuickBird

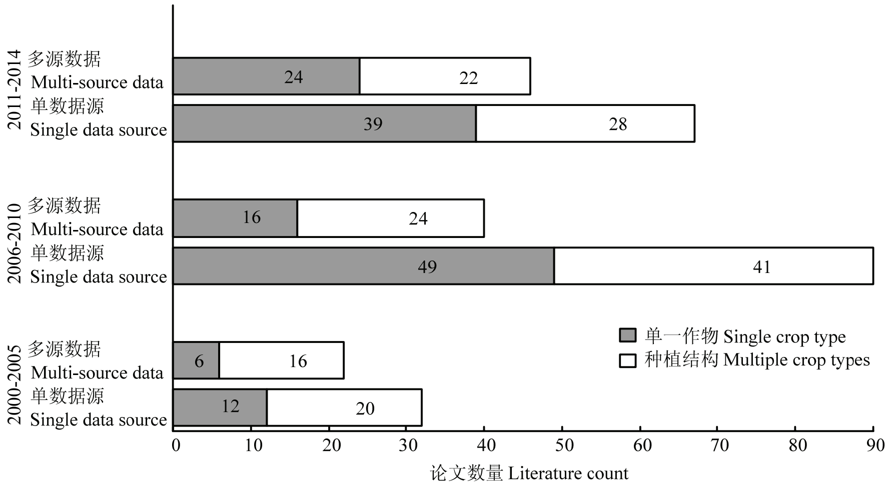
3 3



1
Fig. 1 The review framework



2
Fig. 2 The categorization of crop identification based on different sensors



3

Fig. 3 Statistics of the remote sensing sources used for crop identification

2

[34]

HIS

PCA Brovey

“ ” “

”

[25-27]

[35] Brovey

IHS HJ-1A

ALOS 2.5 m

[28-29]

HJ-1A

12.39% 2008

[30-32] [36]

2.1

MODIS NDVI TM NDVI

30 m NDVI

NDVI

[33]

78.76%

250 m

30 m [37] 12.5 m ASAR-VV

PALSAR-HH 30 m TM

MIMICS

SAR

93.54% 12.5 m

STARFM [38] [39] [40]

[41]

1

2.2

[42]

“

”

“ ”

[43]

TM

MODIS

6

TM

[44]

Landsat TM

Landsat

MODIS

0.8

“ ” Singh[45-46] Watts[47]

Wu[48] Landsat-MODIS

“ - ” Foerster

[49] 30 m 17 Landsat TM/ETM

12

NDVI

[50] 2011 4

10 TM HJ-1

30 m

MODIS TM/HJ-1

30 m NDVI EVI2 WRDVI

4 3

90.53% 91.35% 90.83%

Maselli [51] 12 TM NDVI AVHRR

NDVI

4

Esch [52]

C5.0 2

LISS-3 3 AWiFS

1

Table 1 Fusion of multi-source remote sensing data to improve the spatial resolution

Time-space optimization method	1 Data source 1	Spatial resolution (m)	2 Data source 2	Spatial resolution (m)	Identification method	Study area	Crop types	Identification accuracy	Authors
Image fusion	HJ-1A	30	ALOS	2.5	ISODATA ISODATA unsupervised classification	** Jinhu country,Jiangsu, China	Rice	91.65%	[35], 2012 Nan Jiang et al.,2012
	MODIS NDVI	250	TM NDVI	30	Minimum distance classification	** Yuanyang country, Henan, China	Corn	78.76%	[36],2010 Xin He et al.,2010
A model based on BP neural network and normal fuzzy distribution function	ASAR-VV PALSAR-HH	12.5 10	TM	30	BP A model based on BP neural network	** Changping,Beijing, China	Corn,soybean, wheat and fruit-bearing forest	93.54%	[37],2009 Tianjie Zhao et al.,2009
STARFM	MODIS	500	Landsat TM	30	—	54N 104W*	—	—	Gao [38],2006 Gao et al.,2006
Component substitution	Landsat TM	30	SPOT Pan	10	—	—	—	—	Shettigara [39],2012 Shettigara et al.,1992
Semi-physical fusin approach	MODIS	500	Landsat TM	30	—	** One in Africa and two in the U.S	—	—	Roy [40],2008 Roy et al.,2008
Multiresolution wavelet decomposition	Landsat TM	28.5-120	SPOT Pan	10	—	** Southeas of New Mexic, USA	—	—	Yocky [41],1996 Yocky et al.,1996

** *

** indicates regional scale, * indicates sample region scale

4

“

”

2

3

[53] -

[54]

[55-56] “ ”

3.1

Conrad [57] SPOT

ASTER

Conrad

[58] 7 IRS-P6 AWiFS 35

NDVI ETM+

[59] ETM+

MODIS NDVI 1

24

[60]

MODIS NDVI

TM NDVI

[61] MODIS NDVI

TM

92.39% Zhang [62] MODIS

(ESTDFM) 30 m

ETM+

ISODATA

40

Landsat

MODIS

2

Table 2 Fusion of multi-source remote sensing data to improve the temporal resolution

Time-space optimization method		1 Data source 1	/ Time phases (phase)	2 Data source 2	/ Time phases (phase)	Identification method	Study area	Crop types	Identification accuracy	Authors
Integration of the same data source to extend time resolution	Interpolation of time-series images	TM NDVI	6	MODIS NDVI	The whole growth period	Decision tree	** Yuanyang country, Henan, China	Corn	89.19%	[43],2010 Xiaohe Gu et al., 2010
	Spatial and temporal reflectance fusion technology	Landsat	2	MODIS	6	Spectral Angle Mapper	** Jiangning Country, Nanjing, China	Rice	93.00%	[44],2010 Mingquan Wu et al., 2010
		Landsat	5	MODIS	26	Random forest	** North central Montana, USA	Spring wheat and winter wheat	94.00%	Watts [47],2011 Watts et al.,2011
		Landsat	2004-2008	MODIS	2004-2008	Unsupervised classification	** Hai Basin, North China Plain	Wheat, corn and cotton	88.00%	Wu [48],2012 Wu et al.,2012
	Interpolation of time-series images	TM/ETM+	35	TM/ETM+	35	Hierarchical classification approach based on spectral-temporal profles	** Northeast Germany	Rye, corn, winter wheat, winter barley and oilseed rape etc	65.70%	Foerster [49]2012 Foerster et al.,2012
Integration of the different data source to extend time resolution	Different data source with the same spatial resolution	HJ-1/TM	7	MODIS	15	Minimum distance classifier	* Bole city, Xinjiang, China	- Cotton, cotton-grape, watermelon and corn	>90.00%	[50],2012 Pengyu Hao et al.,2012
	Integration of existing data	Landsat TM NDVI	3	AVHRR NDVI	12	Maximum likehood classification	* Center of Tuscany, Italy	4 Spring crop etc.	0.92[a]	Maselli [51],1998 Maselli et al.,1998
	Different data source with spatial resolution	LISS-3	2	AWiFS	3	C5.0	** Mecklenburg Western, Germany	Corn,rape and commin wheat etc.	86.00%	Esch [52],2014 Esch et al.,2014

** * 1 kappa

** indicates regional scale, * indicates sample region scale; 1 use kappa coefficient

3.2

[63-67]

Bruzzone [68] 2

TM ERS-1 11

Brisco [69] SAR

TM

SAR

SAR SAR

44% SAR TM

2%

[70] Blaes [71] 6 571

39 15 ERS Radarsat

3 Landsat ETM SPOT HRV

ERS Radarsat SAR -SAR

3

-SAR 5%

McNairn [72] 1 2 Envisat ASAR

85% VV-VH

[73]

ASAR-VV

VV

5% [74]

Radarsat-2 TM

87.5%

SAR

SAR

3.3

[75-76] Thenkabail [77] AVHRR SPOT VGT

GTOPO30

1 km CRU 1 km JERS-1 SAR

ISODATA

NDVI

10 km

28 GIAM GMRCA

[78]

MODIS ALOS SPOT-5 2000—

2008

SRTM DEM

[79] 30 m Landsat TM 19.5 m

CBERS 10 m ALOS

DEM

SPAM

[80-81]

[82] 10 km

20 80

4

“ ”

[83]

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