Chapter 4

Wheat Straw Open Burning: Emissions and Impact on Climate Change

Gisela Montero, Marcos A. Coronado,
Conrado García, Héctor E. Campbell,
Daniela G. Montes, Ricardo Torres, Laura Pérez,
José A. León and José R. Ayala

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.76031

Abstract

The state of Baja California, Mexico, is the second national wheat producer. Mexicali, the capital of Baja California, is the primary wheat producer, and it represents the most significant crop in the valley, with 90,609 ha of a cultivated surface by 2015; it leads to a wheat production of 585,334 t and a generation of 661,446 t of wheat straw as agricultural residue. The 15% of this waste has various uses. The 85% of wheat straw is open burnt *in situ* to prepare the farmland for the next agricultural cycle. Through the development of an emissions and energy model on iThink®, the emissions of 6,185 t of PM, 35,983 t of CO, and 1,125 t of CH_4 considering a headfire burning or 3,373 t of PM, 30,360 t of CO, and 731 t of CH_4 by backfire burning were estimated. Also, the wheat straw wasted energy was estimated at 8.15 PJ by 2015, with a lower heating value of 14.50 MJ/kg determined experimentally. The results highlight that for each hectare of harvested wheat, 6.205 t of wheat straw are generated and burnt. It represents the emission of pollutants and 89,972.50 MJ of wasted energy.

Keywords: wheat straw, climate change, open burning, emissions, energy

1. Introduction

Agriculture is the oldest economic sector in the world, and it is more reliant on fertile soils and stable climate than any other type of trade [1]. Nowadays, wheat is one of the key cereals cultivated in the world, with an annual production of 733 million tons by 2015 [2]. In the same year, the harvested surface dedicated to wheat production was 819,928 ha in Mexico [3]. The wheat varieties *Triticum aestivum* and *T. durum* are the most common. In the fall–winter season, 90% of wheat production is obtained, and the remaining 10% in the spring–summer season. The harvest season is performed predominantly in May and June [4].

The Mexicali Valley is one of the most important agricultural areas of the northwest of Mexico, and it has one of the most extensive surfaces dedicated to wheat production nationally. This valley is located on the state of Baja California and shares the atmospheric basin with the Imperial Valley, USA (**Figure 1**). Its principal crop is wheat, with an average productivity of 6.46 t/ha, of the *T. aestivum* variety. Apart from the favorable climate conditions for this crop in the region, the use of improved varieties of a high productive potential and the experience of the producer in the application of the technological innovations for its management had been determinants to achieve this level of production [5]. After harvesting, it is necessary to dispose large amounts of straw generated as agricultural waste, with a rate of 7.3 t/ha [6]. Usually, 85% of this waste is burnt *in situ* in the open air with the objective of preparing the fields for double-cropping or the next agricultural cycle, and the remaining percentage has various applications [7].

Figure 1. Geographic location of Baja California.

http://dx.doi.org/10.5772/intechopen.76031

Some wheat producers of the Mexicali Valley that conduct this practice argue that the burning represents a traditional practice and that the incineration of agricultural waste is necessary since it eliminates perennial weeds, diseases, and pests (**Figure 2**). Other producers ensure that for burning wheat straw, the use of machinery is not a requirement, saving money in machinery, diesel, and the tractor's operator and that it gives more time with the purpose of preparing the fields for the next cycle. However, contrary to the producers' assumptions, the burning calcine nitrogen, phosphorus, and the soil organic matter, as well as generating additional costs and a drop in yield and, in consequence, shrinkages on the utility in obtaining less volumes by wheat hectare between cycle and cycle [8], has been demonstrated.

The *in situ* burning of wheat straw implies the emissions of large quantities of PM, CO, and CH_4 that impact the environment, causing deterioration in the air quality of the Valley, including the city of Mexicali, as well as respiratory diseases for the population (**Figure 3**). In this sense, it is relevant to mention that Mexicali is one of the cities of Mexico with a higher level of morbidity from acute respiratory infections.

The emissions caused by the open burning of wheat straw affect the climate. Consequently, it has an impact on crop growth and yields are negatively affected by suboptimal water supply and abnormal temperatures due to physical damages, physiological disruptions, and biochemical changes [9, 10]. The use of conditional promoters driving gene expression at specific developmental stages, in response to specific environmental cues, will make possible the generation of transgenic crops able to grow under various abiotic stresses with minimal yield losses [11].

Also, when the wheat straw is open burnt, the energy contained in the same is wasted. The wheat straw could be valorized and reconverted into biofuels or directly used in electric generation.

The utilization of bioenergy has significant environmental, and also economic, benefits because the biomass waste is valorized as biofuel. The use of wheat straw as raw material for any productive process presents diverse factors that must be considered. Among those factors

Figure 2. Open burning of the wheat straw in Mexicali Valley, Mexico.

Figure 3. Open burning of the wheat straw near the rural population of the Mexicali Valley, Mexico.

are the low density of biomass, handling and high transportation cost, an attractive heating value, and the physicochemical characterization [12].

In this chapter, the emissions caused by the headfire or backfire burning of wheat straw *T. aestivum* in Baja California, Mexico, for the period 1987–2015, were estimated through the development of a model on the iThink® dynamic simulator [13]. Also, the energy emitted by wheat straw burning was calculated considering its significant heating value of 14.50 MJ/kg determined experimentally [14], and it was included in this model.

2. Materials and methods

The emissions and energy associated with the agricultural burnings depend on many parameters; for that, those supported by current and reliable information were selected. The settings used to feed the model are the following:

1. Historical series of the wheat harvested surface,
2. Wheat straw generation index,
3. Wheat straw lower heating value,
4. PM, CO, and CH_4 emission factors by agricultural burning technique.

2.1. Historical series of the wheat-harvested surface

Wheat straw is a waste generated in large quantities during wheat harvesting. To estimate its generation in the Mexicali Valley, information on the annual wheat harvested surface on the 1987–2015 period was used and is presented in **Table 1** [15, 16].

2.2. Wheat straw generation index and lower heating value

To estimate the quantity of wheat straw generated by agricultural cycle, a generation index of 7.3 t/ha was considered [6].

Year	Wheat-harvested surface (ha)	Year	Wheat-harvested surface (ha)
1987	53,098	2002	74,394
1988	50,572	2003	85,320
1989	48,374	2004	80,555
1990	60,366	2005	75,989
1991	79,683	2006	79,946
1992	79,683	2007	81,958
1993	80,018	2008	88,937
1994	69,658	2009	87,724
1995	53,159	2010	87,321
1996	67,224	2011	74,260
1997	54,913	2012	72,153
1998	50,636	2013	83,015
1999	74,273	2014	81,681
2000	68,033	2015	90,609
2001	64,926		

Table 1. Historical series of the wheat-harvested surface, 1987–2015.

The lower heating value of the wheat straw was considered as 14.50 MJ/kg, which was experimentally determined. The tests were realized with the *T. aestivum* wheat variety from Baja California, Mexico [14].

2.3. PM, CO, and CH_4 emission factors by agricultural burning technique

To estimate the PM, CO, and CH_4 emissions, generated by wheat straw burnt *in situ* in the open air, the factors reported by the EPA AP-42 [17], enlisted in **Table 2**, were used. Such report clusters the emission factors according to the incineration technique used by the farmers. It is important to note that in the Mexicali Valley case, both techniques are used by producers, for which the calculations were made considering the two of them. The incinerating techniques according to the EPA are described as follows:

- Headfire: Burning technique where the fire advances in the wind direction;
- Backfire: Burning technique in which the fire advances to the opposite direction of the wind.

2.4. Parameters used in the emissions and energy model and sequence

Figure 4 displays the sequence and relationships between the parameters used in the emissions and energy model.

Type of burning	Emissions factors (kg/t)		
	PM	CO	CH_4
Headfire	11	64	2
Backfire	6	54	1.3

Table 2. Emissions factors.

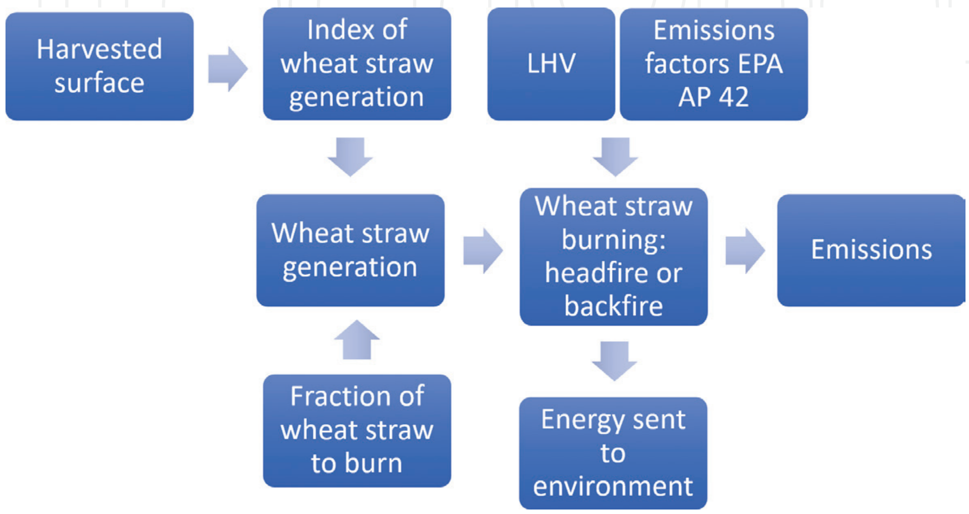

Figure 4. Parameters used in the emissions and energy model.

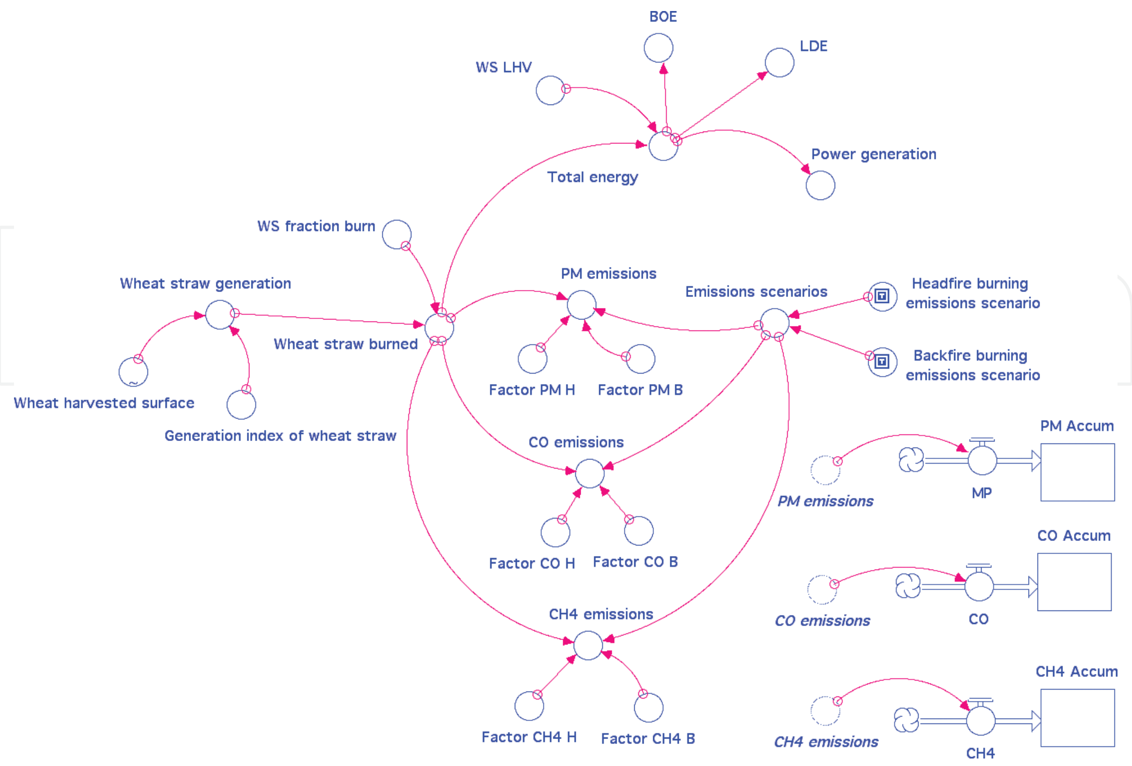

Figure 5. Emissions and energy model developed in iThink®.

2.5. Emissions and energy model

Based on the selected parameters and with the purpose of facilitating the analysis of the emissions associated with wheat straw burning during the 1987–2015 period, a dynamic model was developed on iThink®, whose simplified version is illustrated in **Figure 5**. The development of the model allows to establish and observe practically and graphically the interrelations of the different variables used to estimate the emissions corresponding to wheat straw burning and the quantity of energy generated during the combustion of the agricultural waste under study and associated emissions.

3. Discussion and results

The simulation results indicate that for headfire burning, the annual emissions (PM, CO, and CH_4) increased from 25,370 t (1987) to 43,292 t (2015). While for backfire, the emissions went from 20,197 t (1987) to 34,465 t (2015), which represents an increase of 71%.

Figures 6 and **7** illustrate the accumulated emissions of the period under study. In the headfire burning, 141,951 t of PM, 825,899 t of CO, and 25,809 t of CH_4 are generated. In the backfire burning, the emissions are 77,428 t of PM, 696,853 t of CO, and 16,776 t of CH_4.

The decrease of emission in backfire burning is due to a more significant interaction generated between the wheat straw and the oxygen present in the air because the incineration occurs against the wind which promotes the slow burning of wheat straw and better combustion.

The energy sent to the environment by wheat straw incineration in the 1987–2015 period was estimated at 188.81 PJ, which represents the 2.29% of the primary energy production of Mexico by 2015 [18]. During the analyzed period, there was an increase in the energy sent to the environment that varied from 4.78 PJ in 1987 to 8.15 PJ in 2015. **Figure 8** displays the behavior of the accumulated values of the energy sent to the environment in 1987–2015.

The annual average of discarded energy in the 1987–2015 period was of 6.51 PJ, which represents the 1.81% of the biomass energy in Mexico, 2015 [18]. However, the use of this wasted energy presents some challenges and opportunities that must be taken into consideration, which implies evaluating the technical and economic feasibility of any process.

Figure 9 displays the matter and energy balance corresponding to one wheat hectare harvested in the Mexicali Valley, where the index of wheat production by hectare is of 6.46 t and the generation of wheat straw is 7.3 t. The 15% of wheat straw generated has many applications such as incorporation in agricultural soil, cattle food, construction material elaboration, among others. The 85% of wheat straw, that is to say, 6.205 tons, is openly burnt *in situ*, which represents 89,972.50 MJ of energy sent to the environment and causes pollutant emissions. In the headfire burning, 477.78 kg of contaminants, composed of 68.26 kg PM, 397.12 kg CO, and 12.41 kg CH_4, are generated. In the case of backfire burning, 390.37 kg of contaminants, composed of 37.23 kg PM, 335.07 kg CO, and 8.07 de $CH_{4,}$ are generated.

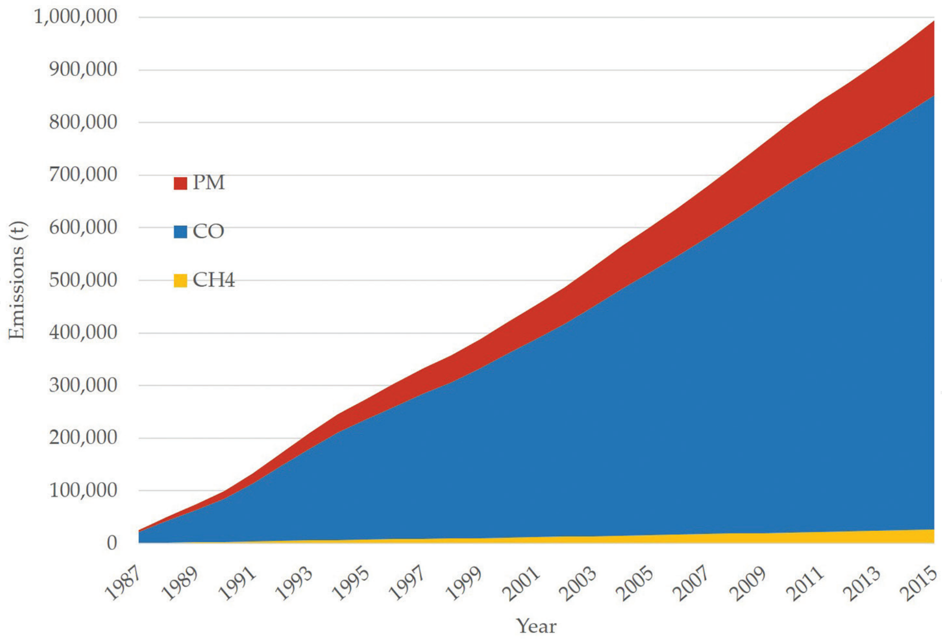

Figure 6. Accumulated emissions by headfire burning.

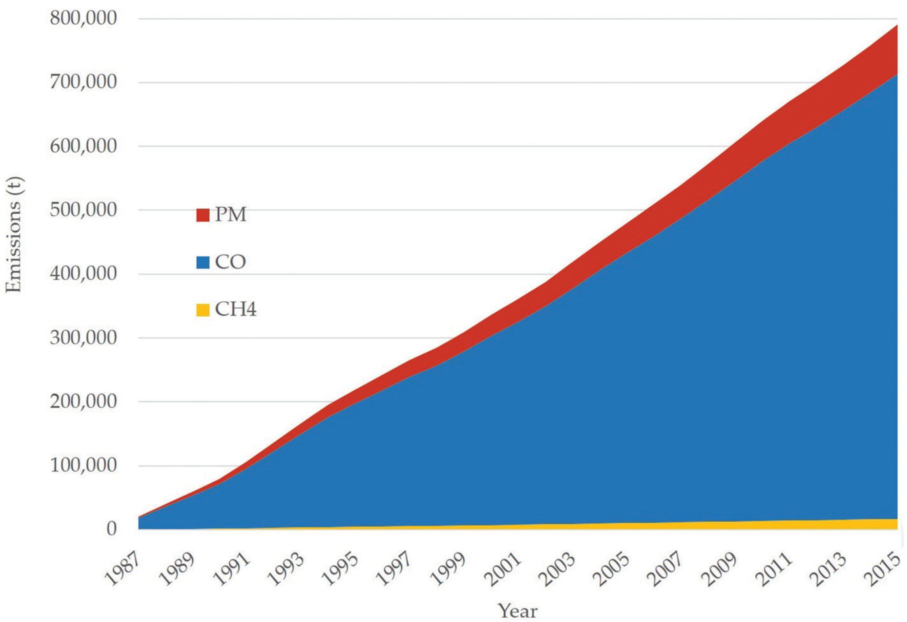

Figure 7. Accumulated emissions by backfire burning.

The balance of energy and matter indicates that for each ton of harvested wheat in the Mexicali Valley, 1,130.03 kg of wheat straw are generated, of which 169.50 kg are used in diverse applications and 960.53 kg are burnt in open air. The incineration of this waste implies that 13,927.63 MJ are wasted without any use, as well as pollutant emissions. In the headfire burning, 73.96 kg of pollutants, composed of 10.57 kg PM, 61.47 kg CO, and 1.92 kg CH_4, are generated. As for the backfire burning, 58.88 kg of contaminants, composed of 5.76 kg PM, 51.87 kg CO, and 1.25 kg CH_4, are generated.

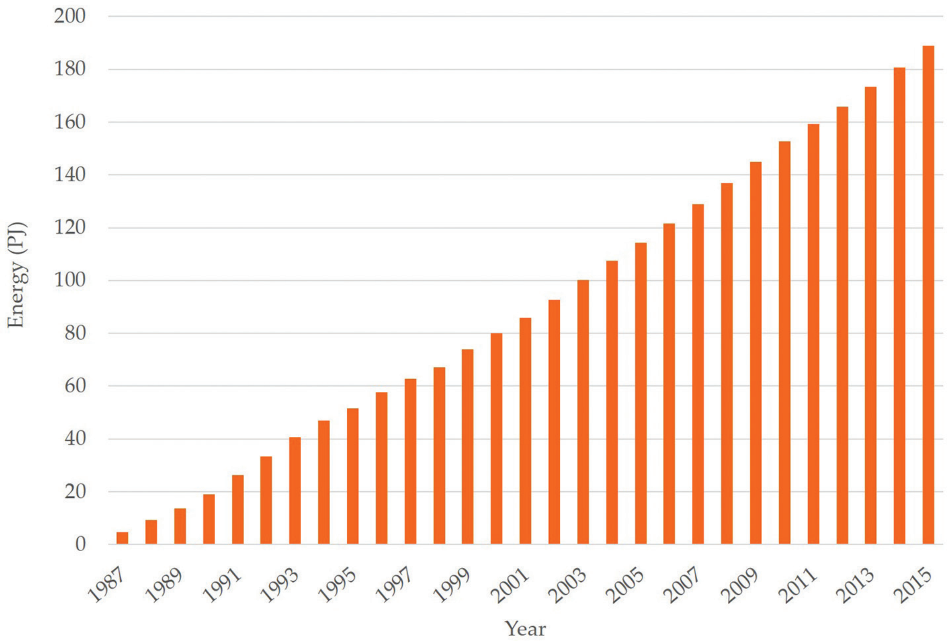

Figure 8. Energy sent to the environment.

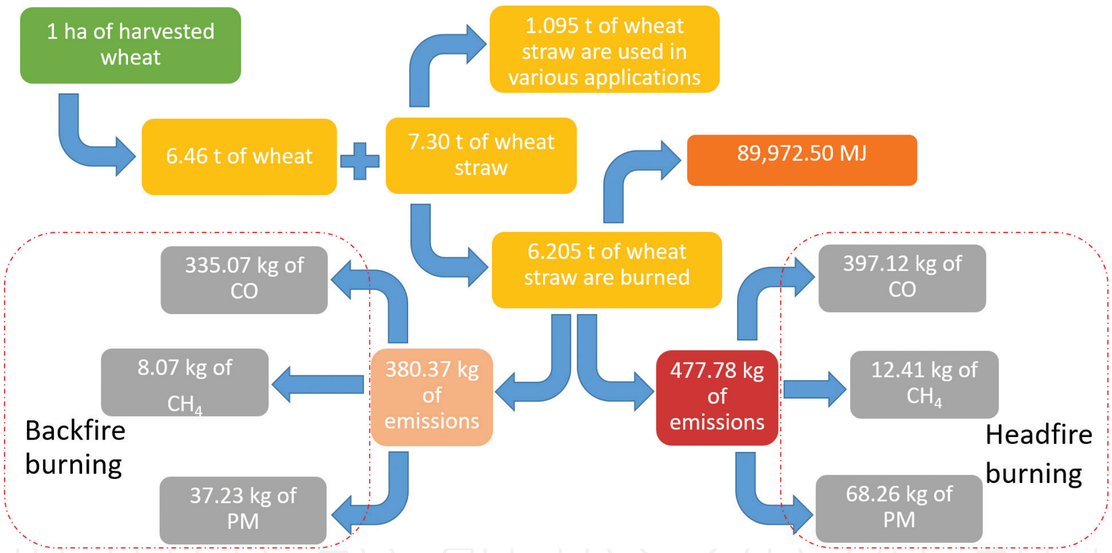

Figure 9. Material and energy balance of one harvested hectare of wheat.

4. Conclusions

Wheat cultivation is an intensive activity of great importance for the economic development of Baja California, Mexico. It also means the generation of vast amounts of wheat straw that is burnt *in situ* and emits large quantities of PM, CO, and CH_4 annually, contaminants that affect the air quality of Mexicali and its valley.

Since 1987 until 2015, the sown surface of wheat has incremented in the Mexicali Valley, resulting in an increase in the polluting emissions and the wasted energy.

Also, the total available energy estimated, draw from wheat straw incineration, for the 1987–2015 period is 188.81 PJ, which represents a high energy potential that can be exploited in productive processes.

Through the development of the model on iThink®, the emissions and the wasted energy, as a result of wheat straw burning, were estimated in the period under study. It demonstrates the severity of the problem and justifies the necessity of promoting sustainable alternatives for the disposal of wheat straw, with a lower environmental impact, among the farmers of the region.

According to the model of headfire burning, the results of the simulation indicate that the annual emission increased from 25,370 t (1987) to 43,292 t (2015), while for the backfire burning from 20,197 t (1987) to 34,465 t (2015), which represents a rise of 71%.

The balance of matter and energy results, developed in the current work, for 1 hectare of wheat harvested in the Mexicali Valley shows that 6.46 t of wheat are produced and 7.3 t of straw are generated; 6.205 t are burnt *in situ* in open fire, which generates 89,972.50 MJ and 477.78 kg of contaminants by the headfire burning and 380.37 kg of pollutants through backfire burning.

Acknowledgements

The authors thank the Engineering Institute of Universidad Autónoma de Baja California, for the facilities to develop this project, and PFCE 2017 for the financial support for the publication of this chapter.

Author details

Gisela Montero*, Marcos A. Coronado, Conrado García, Héctor E. Campbell, Daniela G. Montes, Ricardo Torres, Laura Pérez, José A. León and José R. Ayala

*Address all correspondence to: gmontero@uabc.edu.mx

Universidad Autónoma de Baja California, Institute of Engineering, Mexicali, México

References

[1] Fahad S, Nie L, Chen Y, Wu C, Xiong D, Saud S, Hongyan L, Cui K, Huang J. Crop plant hormones and environmental stress. In: Lichtfouse E, editor. Sustainable Agriculture Reviews. 1st ed. Cham: Springer; 2015. pp. 371-400. DOI: https://doi.org/10.1007/978-3-319-09132-7_10

[2] FAO. Cereal Supply and Demand Brief [Internet]. 2016. Available from: http://www.fao.org/ worldfoodsituation/csdb/en/ [Accessed: Jan 15, 2018]

[3] Agrifood and Fisheries Information Service. Statistical Yearbook of Agricultural Production [Internet]. 2015. Available from: https://datos.gob.mx/busca/dataset/estadistica-de-la-produccion-agricola/resource/2a3fea18-00a4-461f-abf8-15bda6b131e3?inner_span=True [Accessed: Jan 21, 2018]

[4] Current situation and overview of wheat production in Mexico 1990-2000 [Internet]. 2005. Available from: http://www.campomexicano.gob.mx/portal_siap/Integracion/Estadistica-Derivada/ComercioExterior/Estudios/Perspectivas/Trigo90-00.pdf9 [Accessed: Feb 1, 2018]

[5] SAGARPA. Plan rector del sistema producto trigo, Baja California [Internet]. 2011. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, México. Available from: http://www.sagarpa.gob.mx/agricultura/Publicaciones/ SistemaProducto [Accessed: Dec 12, 2017]

[6] SENER, BID, GTZ. Potenciales y viabilidad del uso de bioetanol y biodiesel para el transporte en México. Secretaría de Energía, Banco Interamericano de Desarrollo, Cooperación Técnica Alemana. [Internet]. 2006. Available from: http://www.sener.gob.mx/res/169/Biocombustibles_en_Mexixo_Estudio_Completo.pdf. México, D.F. 600 p. [Accessed: Dec 20, 2017]

[7] Quintero M, Moncada A. Contaminación y control de las quemas agrícolas en Imperial, California, y Mexicali, Baja California. Región y Sociedad. 2008;**20**:3-24. DOI: 10.22198/rys.2008.43.a494

[8] SFA. Estudio sobre la utilización de la paja de trigo [Internet]. 2010. Available from: http://www.oeidrus-bc.gob.mx/oeidrus_bca/ [Accessed: Nov 29, 2017]

[9] Fahad S, Bajwa A, Nazir U, Anjum S, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S, Ihsan M, Alharby H, Wu C, Wang D, Huang J. Crop production under drought and heat stress: Plant responses and management options. Frontiers in Plant Science. 2017;**8**:1-16. DOI: 10.3389/fpls.2017.01147

[10] Amanullah FS, Anwar S, Baloch S, Saud S, Alharby H, Alghabari F, Rice IM. Crop responses to global warming: An overview. In: Amanullah FS, editor. Rice – Technology and Production. 1st ed. Croatia: InTech; 2017. pp. 1-10. DOI: 10.5772/68035 Available from: https://www.intechopen.com/books/rice-technology-and-production/rice-crop-responses-to-global-warming-an-overview

[11] Fahad S, Hussain S, Matloob A, Khan F, Khaliq A, Saud S, Hassan S, Shan D, Khan F, Ullah N, Faiq M, Khan M, Tareen A, Khan A, Ullah A, Ullah N, Huang J. Phytohormones and plant responses to salinity stress: A review. Plant Growth Regulation. 2015;**75**:391-404. DOI: https://doi.org/10.1007/s10725-014-0013-y

[12] Montero G, García C, Coronado M, Toscano L, Stoytcheva M, Torres R, Vázquez A, Montes D. SWOT analysis applied to wheat straw utilization as a biofuel in Mexico. In: Jacob-Lopes, editor. Frontiers in Bioenergy and Biofuels. 1st ed. Croatia: InTech; 2017. pp. 483-493. DOI: 10.5772/65496 Available from: https://www.intechopen.com/books/frontiers-in-bioenergy-and-biofuels/swot-analysis-applied-to-wheat-straw-utilization-as-a-biofuel-in-mexico

[13] iThink. Iseesystems [Internet]. 2018. Available from: https://www.iseesystems.com/ [Accessed: Feb 1, 2018]

[14] Montero G, Coronado M, Torres R, Jaramillo B, García C, Stoytcheva M, Vázquez A, León J, Lambert A, Valenzuela E. Higher heating value determination of wheat straw from Baja California, Mexico. Energy. 2016;**109**:612-619. DOI: 10.1016/j.energy.2016.05.011

[15] SAGARPA. Serie histórica de producción de trigo grano, sistema producto trigo [Internet]. 2011. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, México. Available from: http://www.oeidrus-bc.gob.mx/sispro/trigobc/ [Accessed: Nov 10, 2017]

[16] OEIDRUS. State Information Office for the Sustainable Rural Development of Baja California (Oficina Estatal de Información para el Desarrollo Rural Sustentable de Baja California) [Internet]. 2016. Available from: http://201.140.167.37/series/ [Accessed: Jan 22, 2018]

[17] EPA. Compilation of air pollutant emission factors. Volume I, Chapter 2: Solid Waste Disposal, Open Burning [Internet]. 1995. Environmental Protection Agency. EPA AP 42, 5a ed. Available from: https://www3.epa.gov/ttnchie1/ap42/ch02/index.html [Accessed: Feb 4, 2018]

[18] SENER. Balance Nacional de Energía 2015. [Internet]. 2016. Available from: https://www.gob.mx/cms/uploads/attachment/file/248570/Balance_Nacional_de_Energ_a_2015__2_.pdf [Accessed: Jan 29, 2018]