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INFORMATION TECHNOLOGY FOR USERS' BASED WATER RIGHTS ENFORCEMENT

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ABSTRACT
Mexico faces a critical challenge of groundwater depletion caused mainly by farmers extracting water illegally or in excess of their concession. The country already has a set of rules for sustainable use of the aquifers: It has a system of registered concessions with volume limits on groundwater, it has laws to penalize whoever makes use of the national waters without permit or exceeding its concession, it has a mechanism that allows the trade of these extraction volumes, and it has a program of aquifer-level associations (called COTAS) to manage the use of groundwater. So, if the country has all these rules and regulations, why is it not working, why is the groundwater use not sustainable? Our argument is that the problem lies in the lack of transparency in the usage information, in the users' perception of water as an unlimited resource due to poor law enforcement, and a complicated access to the data of concessions for those who might want to use the existing legislation to protect an aquifer.

What cannot be seen cannot be protected. But if indirect measurements are made, through a simple equation that links energy use, depth of the water table, and volume of water extracted, and these are made visible in an open internet platform aimed to publish the use (and abuse) of the aquifers; citizens, the regularized farmers, the companies and the localities would have the tools needed to take action. Individually or collectively, they could denounce or sue those who are not respecting the volume of their concessions, demanding that authorities take action. They could alternatively offer options to those who are not doing things correctly: agreements, contracts or financing to modernize towards water-efficient technology are some of the possibilities. They could as well be legalized using water markets or bilateral agreements between farmers, local governments or companies.

With diverse stakeholders being able to use this inclusive platform, community participation would be promoted, a reduction in water extraction from the stressed aquifers would be achieved, and the tragedy of commons would be prevented by creating a sense of ownership. Such platform would therefore achieve authentic inclusive green growth, and would represent an important step in Mexico for reaching the UN sustainable development goal of sustainable water use for everyone.

Keyword: *aquifer overdraft, online platform, community participation, transparency, water governance*

1. INTRODUCTION

Groundwater use has rapidly expanded across the world as population increases and with it the demand for a stable source of water (Siebert, Burke, Faures, et al., 2010). Groundwater use has had positive impacts such as increased agricultural productivity and incomes, however, poor administration, and unsustainable public policies such as energy subsidies for pumping have lead water extraction to exceed the natural recharge rate in many aquifers around the world. This phenomenon is called aquifer overdraft and leads to declined availability and deteriorated quality of water (Scott & Shah, 2004).

1.1 Water Usage in Mexico

Mexico is one of the most important groundwater users of the world and it has a critical overdraft situation: 37% of its 282 most important aquifers are overexploited (Aguirre, 2011, p. 2). In 2009, 80.6 cubic kilometers were Mexico's total use of water, of which 77% were used for the agricultural sector (Ramo-Vázquez, 2013). Of its total agricultural use, 66% came from surface sources and 34% from the underground (CONAGUA, 2011) (see Table 1). Approximately, 60.5% of the water extracted from the Mexican aquifers is used for agriculture (CONAGUA, 2014), thus, proper management of groundwater irrigated agriculture is critical for sustainability, and will be the focus of this paper.

Table 1: Extraction of underground and superficial water in Mexico by type of use, 2009. (cubic kilometers)

Type of Use	Total	Superficial	Underground
Agricultural sector	61.8	40.9	20.9
Public	11.4	4.3	7.1
Industrial (without thermoelectric plants)	3.3	1.6	1.7
Thermoelectric plants	4.1	3.6	0.4
Total	80.6	50.5	30.1
Note: Highlighted cell shows the use in which this paper focuses.			

Source: own elaboration with data from CONAGUA, 2014a.

1.2 Water Legislation in Mexico

The Mexican Constitution states in its Article 27th that "*The property of land and water within the national territory corresponds to the nation which can transmit their domain to particulars through the private property*". CONAGUA (National Water Commission) is the government organism in charge of the integral management of the hydric resources. Through CONAGUA, the government is able to give permits to particulars for the exploitation of water resources, however, these permits, called "concessions" in Mexico, can be withdrawn for several reasons, some of which are: (1) overpassing the authorized levels of extraction by more than 20%, (2) extracting or using underground waters in restricted zones without the previous authorization of the waters authority, (3) damaging ecosystems as a consequence of the use of national waters or (4) transmitting the water rights without permission or without following the indications stated in the Law.

Regarding payments, according to the article 223 of the Federal Water Rights Law, a fee applies to anyone that uses, exploits, or makes use of national waters. This fee varies depending on the availability zone, the type of water (surface or groundwater) and the use to which it is aimed. The agro-livestock sector is the only one exempted from fees for the usage of water. However, fees apply if the volume allowed for extraction to each individual is surpassed, in this case a fee of $0.1632 MXN (around $0.009 USD) per cubic meter surpassing the allowed volume is charged (Ley Federal de Derechos, 2015). The concessioners have, at least in theory, a set of obligations which include to install water-meters and keep them in good shape, and to punctually pay the fees or fines established by the Law regarding their real consumption.

According to the Public Water Rights Registry (REPDA) there are 252 thousand concession titles (REPDA, 2016), from which 48% are for agricultural use. Among agricultural users in particular, the requirements for water meters are mostly not met, yet no consequence is imposed on them; they still can hold their concessions, without enforcement of the regulations. Government agencies seem reluctant to take any action against powerful agricultural organizations, and our argument is that the fact that this lack of compliance is not evident to other water users in the agricultural sector, in industry or household users, is precisely what allows government agencies to have this level of tolerance.

1.3 Water Market (Banks) in Mexico

In the system of water concessions that has been in place since the 1990s the only possible way to acquire permits in "water-scarce" aquifers, where concessioned volume would equals or exceeds the natural recharge, was by transmission of rights from other users through *ceding* (giving without monetary compensation) part of their concession. Since the law essentially prohibited the sale of water rights, some profitable illegal market transactions emerged (Reis, 2014) but mostly it inhibited transmission of rights.

In 2011, a reform allowing a legal water market to exist was finally introduced in Mexico. This water market reform now allows the sale of water rights and intends to fulfill the need of an economic incentive for optimization of water use. A farmer has now the legal right to modernize with water saving technologies, through government credit programs for example, and finance this through the sale of the surplus water she would obtain through the modernization, and then sell part of her concession volume to other farmers operating in the same aquifer (CONAGUA, 2012). In theory, this would work well, however, without proper measurement and regulation of extraction, there is no economic incentive whatsoever to decrease the water consumption or to acquire more water rights. Without enforcement against illegal extraction, the price of the water would never be able reach a balance reflecting the supply and demand under sustainability limits.

1.4 Technical Committees for Underground Water (COTAS)

By the beginning of the decade of the 1990s, it was clear to CONAGUA that effective groundwater regulation would be unlikely to be reached only by the implementation of "top-down" regulatory approaches like those mentioned previously. It was necessary to involve the users with some kind of self-regulation system (Foster, Garduño & Kemper, 2014). Around 1992 the first Technical Committees for Underground Water (COTAS for its initials in Spanish) were created by CONAGUA in the state of Querétaro (Wester, Sandoval-Minero & Hoogesteger, 2011) and were replicated in other agricultural regions of the country.

COTAS are local water-management organizations composed by well owners of an aquifer, local officials from the watershed, and officials from the municipal government. They are an effort to achieve sustainable, self-managed groundwater use and to act as a negotiation-table complement to government regulation. Some of the proposed duties for the COTAS, according to CONAGUA's Inspection and Measurement Direction (2013) are: (1) knowing the information and documentation timely and reliably regarding water permits, water uses, and water availability, (2) widely disseminate among its members and society the information and documentation collected enriched with recommendations and observations, (3) creating a culture of water as a vital and scarce resource, with an economic, social and environmental value and (4) promote the implementation and support the government programs and legislation created to preserve the aquifer's sustainability.

Today, after 20 years of their creation, the COTAS have not achieved the expected results as there has not been a significant reduction in groundwater extraction. Foster, Garduño & Kemper (2014) argue that the poor performance of COTAS is due to a lack of collaboration between them and government organizations, with a lack of law enforcement, legal procedures, and assertive political decisions. While it is true that any "bottom-up" actions must be facilitated by the "top", it is our shared opinion that without proper data transparency regarding permits and real extraction volumes among the users of an aquifer, little work can be done by the COTAS, even with the full disposition of CONAGUA.

Unlike surface waters, where users can easily "see" the amount of water used by each of them, and therefore are forced to collaborate, the "invisibility" of groundwater poses an obstacle to determine the real volumes used by each, and since they operate with relative independence, a tragedy of the commons is prone to happen. Without an enabling environment, and without being provided with the necessary data and tools, it is now clear that COTAS do not have the means to contribute to effective groundwater management (Wester, Sandoval-Minero & Hoogesteger, 2011).

2. THE PROBLEM: AQUIFER OVERDRAFT IN MEXICO

2.1 Overview

Today, 37% of the 282 of the most important aquifers in Mexico are overexploited (Aguirre, 2015). In the 11 most stressed, the extraction rates are between 200% and 800% of the natural

recharge rates (Guevara-Sanginés, 2006). Most of them are located in arid or semi-arid agricultural zones, others around the areas where industrial centers grow fastest.

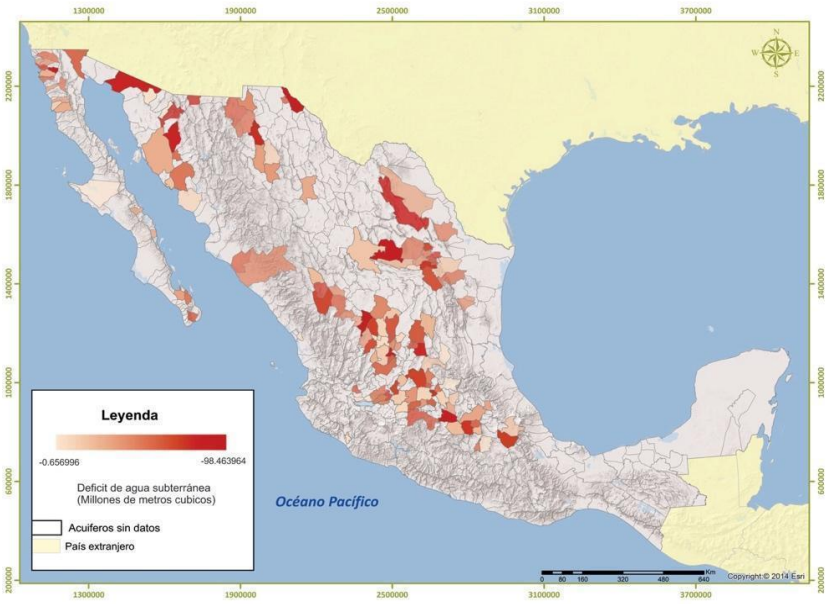

Figure 1: Overexploitation of aquifers in Mexico (Source: Adaptation from Aguirre (2011))

The three main causes of overexploitation of aquifers in Mexico are (1) over-concessed aquifers, (2) users whose water extraction exceeds their concession and (3) illegal wells. Each of these will be discussed in this section of the work.

2.2 Over-concessioned aquifers

An over-concessioned aquifer is one in which the total volume of water allowed by the government for extraction exceeds the natural recharge rate of the aquifer (sustainability limit). This problem is usually either a consequence of political issues or lack of information at the moment of granting the extraction permits. The magnitude of this problem is easy to calculate, since the data is available, through the following equation published in the Mexican Water Use Standards (NOM-011-CNA-2000):

Mean annual groundwater availability	=	Mean total annual recharge	-	"Set aside" natural flow	-	Concessioned volume of groundwater

When the sum of the "set aside" natural flow and the concessioned volume is greater than the mean total annual recharge, then a negative availability exists, called a deficit, and therefore is said that the aquifer is over-concessioned. In a study of availability carried on by CONAGUA in 2013 it was determined that there are 192 aquifers with deficit in Mexico, representing a total deficit of 6,471 millions of cubic meters (CONAGUA, 2014). More than half of the water extracted from the 15 aquifers with higher deficit is used for agriculture, with the exception of the aquifers that supply Toluca and Mexico City (CONAGUA, 2014). This is not surprising if we consider, as mentioned earlier on this document, that 60.5% of the groundwater extracted in Mexico is used for agriculture. Over-concession emerges from either of the next two reasons: (1) the natural recharge rate of the aquifer decreases due to natural or human-induced changes in climate or hydrogeology or (2) CONAGUA granted more water rights than the natural recharge rate. The latter is usually the case (Ruiz, 2016). This generally happens due to economical, political or social pressure (even perhaps involving corruption) (Jiménez, Torregrosa & Aboites, 2010). Reducing the concession is hard and can imply serious social and economical issues, however, with an effective water market

in action it might be a possibility for CONAGUA to *buy back* water rights from the users that effectively reduce their water consumption thanks to modernization. This would help to stabilize an aquifer. However, illegality problems remain.

2.3 Wells extracting more water than what was allocated

Ideally, the volumes of extraction are self-declared by the irrigators, however, declared volumes are rarely close to the actual extraction (Guevara-Sanginés, 2006, p. 4). CONAGUA has diverse ways for monitoring, the two main methods used for directly measuring the volumes of extraction are: (1) installing a water meter and monitoring it sporadically using inspectors or (2) automated measurement, which consists in water meters that send a signal to a data-logger, which then sends it directly to CONAGUA. Both the user and CONAGUA have access to the data, which has a low uncertainty level of 1%, according to Rodriguez-Tirado (2015).

According to the interview with Manager of Inspection and Measurement of CONAGUA, José Antonio Rodríguez-Tirado (2015), self-declaration increased between 37% and 61% in some, mainly industrial-use, aquifers after water meters were installed. Since the self-declarations were for industrial uses and therefore have to pay a fee, they represented an important rise in the incomes of CONAGUA, which can be then invested in subsidizing the installation of more water meters. However, these methods for measuring are only cost-effective for their use in the industrial and services sectors, since the initial investment of the installation of the meters is recovered with the increase in the water rights payments. Because the agricultural sector is exempted from those payments, the government's installation of meters for this sector generally represents an economic loss. In addition, the wells devoted to agriculture are usually in rural areas, sometimes remote, where the meters can be stolen or destroyed easily. Therefore, it is not surprising that the problem of users not respecting their concession limits is concentrated in the agricultural sector. We can summarize the reasons of this problem in four main issues: (1) the lack of an effective and reliable (dishonesty-proof) method for measuring water consumption, (2) the hassle to find easy-to-understand information regarding the volumes concessed to each farmer, (3) the lack of incentives to denounce over-exploiting farmers since extraction by anyone is regarded as unlimited due to poor law enforcement, and (4) the lack of an incentives for using the current water market system and modernizing the irrigation systems. The solution proposed further in this document will mainly approach these issues.

2.4 Illegal wells

A third problem are those wells extracting water without even having a concession. It is estimated that approximately 26% of farmers in Mexico extract water without any permit (Guevara-Sanginés, 2006). Satellite images, which reveal irrigated areas in arid zones during the dry season, are used by CONAGUA to identify illegal extraction of water, together with a body of inspectors operating. Most of the illegal wells are located and classified, the real challenge thus resides in law enforcement. On the one hand, the regularization of the illegal wells would only increase the problem of over-concession and make the recovery of the aquifers' sustainability even harder in the future. On the other hand, closure of wells and penalization of farmers has brought serious social and economic consequences in the past. The current status of these illegal wells is "in process of regularization" (Guevara-Sanginés, 2006) which is a passive way of indicating their "tolerated" illegal state. Competition between farmers could be an incentive to denunciate illegal extraction of water, however, this is not usual, because of the lack of response from the government, leading farmers to join the illegal practices, potentially ending in a tragedy of the commons (Rendón-Pimientel L., National Manager of Irrigation Districts, personal communication, August, 2015).

2.5 Review of the problem

In the following diagram the three parts of the problem discussed previously are summarized and conceptualized:

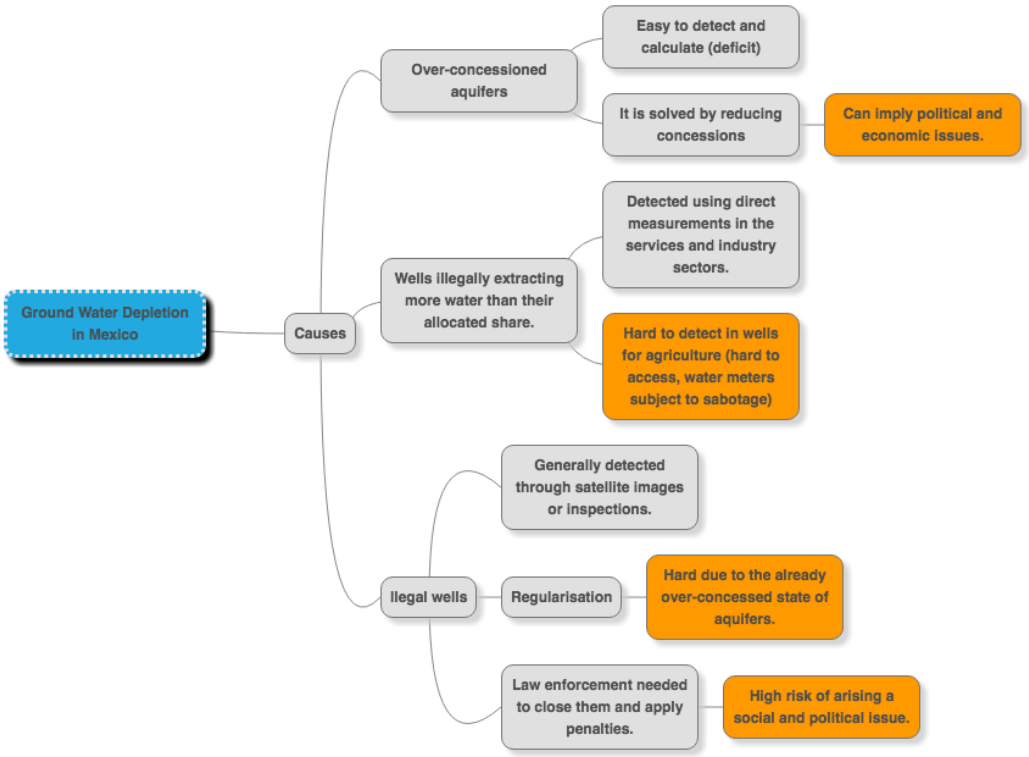

Figure 2. Causes of groundwater depletion in Mexico. (Source: Own elaboration)

3. PROPOSAL

In the first section of this work we reviewed the legal background of Mexican water legislation and the set of problems driving overexploitation of aquifers in Mexico was analyzed and discussed. In this section, we propose a keystone solution based on information technology and transparency.

3.1 The Idea

The objective is to create an information system, published online in a free access web-page, that works as a democratic empowerment tool. A visually attractive online platform that publishes in an easy-to-understand format the data about the real water volume extracted by each concessionary in an aquifer, comparing it to the maximum volume allowed under his concession, thus evidencing illegal extractions. It would as well summarize the aggregate state of the aquifer and its current trends, making special emphasis on the economic, social and environmental costs the trends could bring in the future. In the case of stressed aquifers, it will calculate each user's contribution to the overall overdraft. In the same platform, the users will find a set of "tools for action" that will guide them through different options available for moving towards a sustainable use of their resource. The three main functions of the platform are summarized in figure 2.

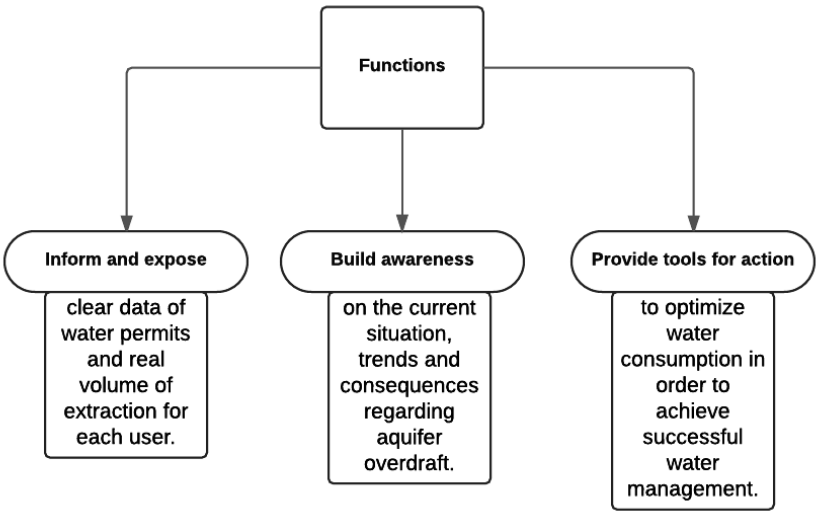

Figure 3: Main functions of the platform.

Tools for action
Within the "tools for action" section, the platform will: (1) share knowledge about available water optimization technology, (2) share updated information regarding loans and government subsidies for modernization, (3) function as a facilitator for the water market, by identifying and connecting users with surplus water to those over-extracting, and (4) provide legal advice on how to denounce or sue illegal extractors, which would be easier now since Mexico has recently allowed class action suits for environmental claims (CIDAC, 2013). Water users could employ the platform's information as motive and evidence to sue concessionaires extracting more water than allocated or illegal wells.

Simple and visual user experience
One of the main characteristics of the platform is its universality and transparency. Anybody should be able to use it, from government officers and researchers, to smallholder farmers in rural areas. For this reason, information should be presented and arranged in a visual and understandable way. The value of the platform is more than just the raw data collected, analyzed and made available, it is the way this information is processed and presented. Data will be displayed in tables, graphics, maps and diagrams that give a sense of tangibility to the "invisible" resource of groundwater. Data will be understandable according to context, and helpful for taking decisions.

Who will manage it and who will use it?
The platform could be managed either by a government agency by itself, such as CONAGUA, or by a partnership between civil society and government. Studies made in Chile by Delgado, Bachmann and Oñate (2007) conclude that any effective governance exercise should be based on (1) involvement of all actors, (2) transparency and openness in the decision taking and (3) access to information through effective and open communication, among some others (Delgado et al., 2007). Since the platform we propose is of public access, anybody can use it. From responsible produce buyers who want to verify the sustainable practices of a particular farmer to government officials. However, we would expect to see *observatorios ciudadanos* (Citizen observatories) and COTAS specially embracing the platform for their regular operations. In the last years, Mexico has observed a rapid increase in civil organizations called *observatorios ciudadanos* that follow up public policies of general interest, specially those that can be quantifiably evaluated (Fundación Este País, 2009). In the information system of *observatorios ciudadanos* (http://www.observatoriosciudadanos.org.mx/) it stands out that policies regarding environment protection are specially attended, together with those of urban and economic development. COTAS would finally have access to the data needed to bolster their self-regulation and to request concrete law enforcement actions by CONAGUA or other regional water authorities. Overall, this platform will provide individuals, NGOs, industries and governments the tools needed for decision

taking and applying peer pressure, starting from the idea that water is a limited resource which is shared by all users.

3.2 Data sources and information display

As it can be inferred, the platform would need a wide variety of data that can be acquired from different sources. It is not the aim of this work to detail the technological or logistical aspects of the platform proposed. However, a brief description of the recommended design for the "inform and exposure" function is offered in this section.

The platform will give the possibility to access the the following data for each aquifer: (1) the watershed they belong to, (2) their location, (3) their situation (non-stressed/overdraft), (4) their status (over-concessioned, illegally over-extracted or both) and the quantitative value of the availability/overdraft. Then, it will display a detailed list of all the concessioners showing: (1) the title name, (2) the volume concessed, (3) the real extraction volume, (4) the quantitative value of the concessions surplus/excess and (5) the contribution of each concession to the aquifer overdraft (when applicable). Table 2 illustrates a sample of the possible arrangement of the information.

Table 2: Illustrative example of information display

Watershed: Lomitas	Aquifer: Bajío
Situation: Critical Overdraft → over-extracted	Availability/ overdraft: -4,578,752m3

Concessionary	**Concessioned volume (m3/year)**	**Real extraction volume (m3/year)**	**Concession owner's surplus or excess**	**Contribution to aquifer overdraft**
Joseph Lopez	654,000	716,094m3	-62,094m3 (excess extraction)	1.35%
Juan Perez	400,000	260,000	140,000m3 (remaining volume)	0%

Most of the data needed for this function will be acquired from public government databases on the internet. Table 3 details the information coming from this type of sources.

Table 3: Sources of the general data for the platform

Data	Source
Aquifer name, watershed and location	Will be obtained from Mexico's Geographic Water Information System (SIGA) database, which includes 653 aquifer and 13 water basin archives available that are constantly actualized on the official webpage (SIGA, 2016).
Aquifer recharge and discharge	In order to calculate an aquifers availability, the volumes of natural recharge and discharge are needed. This information is available from CONAGUA and is published on the Federal Official Gazette. It includes information from all 653 aquifers and is updated every three years (Diario Oficial de la Federación Mexicana [DOF], 2015).
Concession titles and extraction permits	The concession titles will be retrieved from the Public Registry of Water Rights (REPDA) database. Each concession title includes the name of the owner, the volume they are allowed to extract and the location of his/her wells (CONAGUA, 2016).

With this data on hand, only the "real extraction volumes" are needed to perform the calculations needed.

Real extraction volumes
Due to the complications of direct measurement of water extraction in rural areas, CONAGUA has developed a method to indirectly calculate the volume of water pumped by using data of energy consumption and water pump efficiency. However, these method has not been widely used in México due to lack of collaboration between CONAGUA and the Federal Electricity Commission (CFE) (Rodríguez-Tirado, 2015). The formula with which these calculations are made is specified in the article 229 of the Federal Water Rights and is the following:

$$VAEE = \frac{368.073413 * EF * e}{Ha}$$

Where "VAEE" is the estimated volume of extracted water (in cubic meters), 368.073413 is the relation constant between water density, gravitational constant and time units (in hours), "EF" is the energy billed (in kilowatt-hours), "Ha" is the depth of the water table (in meters) and "e" is the efficiency of the motor-pump system. Table 4 specifies the sources of the information needed for the formula.

Table 4: Real extraction volumes data sources

Data	Source
Electric bill	CFE has all the data regarding energy billed in kilowatt-hours to every farmer. Agreements with CFE would therefore be necessary.
Depth of water table	The depth of the water table for each aquifer will be obtained from the groundwater availability archives published on the federal official gazette, *Diario Oficial de la Federación (*DOF*)*, which has information on each of the 653 aquifers. Last update was on April 20, 2015 (DOF, 2015).
Efficiency of motor-pump system	The efficiency of the motor-pump system could be obtained by performing electromechanical efficiency tests in each motor-pump system such as the Mexican Institute for Water Technology (IMTA) did in Zacatecas (González-Sánchez et al., 2015).

In order to obtain the information regarding aquifers' overall situation, the quantitative surplus/excess of each user, and their contribution to aquifer overdraft, some basic calculations have to be done automatically by the platform.

Quantitative surplus/excess for each user
Concession owner's surplus or excess will be calculated by taking the concessionaire's allocated extraction volume and subtracting the real extraction volume calculated with the formula presented before. Positive results mean the farmer has surplus water in his concession, negative results imply he is extracting more water than his permit allows him to.

Aquifers situation
Aquifers availability will be estimated by subtracting the natural discharge plus the sum of all the real extraction volumes of an aquifer to the natural recharge of the aquifer. (note that CONAGUA's definition of availability is different to the one used here, they subtract the total concessioned volume instead of the total real extraction volume [CONAGUA, 2014a]).

$$Availability = natural\ recharge - \Sigma\ real\ extraction\ volumes - natural\ discharge$$

If the result is negative, it means the aquifer has an overdraft problem because: (1) water users are not respecting their limits, (2) the aquifer is over-concessioned, (3) both. To determine which is

the case, the result will be automatically compared to the "deficit" of the aquifer, which is, as mentioned previously, the volume by which the aquifer is over-concessioned. If the result is positive, the aquifer is non-stressed, unless there is a significant amount of water extracted by illegal wells for which the real extraction volume was not calculated.

Contribution to aquifer overdraft
This value will be useful to set priorities as to which users should be called to decrease their extractions more urgently in aquifers with an overdraft problem. It is an indicator of the importance of each user's excess extraction in relation to the total overdraft volume. This information will appear as a percentage and will be calculated by the following formula:

$$Contribution\ to\ overdraft = \frac{Volume\ exceeding\ concession}{Aquifer\ overdraft\ volume} * 100$$

3.3 Expected Outcomes

With the platform released, we would expect to see different consequences in the short, medium and long term:

Short Term:

- With the data of the approximate real extraction volumes available, monitoring costs will significantly drop for CONAGUA, since meter installations would not be needed in remote locations and inspectors would not be necessary.
- Some authors suggest peer pressure could have a positive effect on resource management, even more powerful than traditional incentives (Conniff, 2014; Mani, Rahwan & Pentland, 2013). With the publication of the names of the "over-extracting" farmers, we expect to see an important decrease of water over-extraction due to self-regulation, as a consequence of peer pressure.
- The easy and clear interface of the portal, and the graphics illustrating water availability, would make the "invisible" groundwater finally visible for everybody, this would gradually shift the perception of groundwater from an unlimited resource to a scarce one. They would work as the "Smart meters" in California do, making even their own users be aware of the consequences of their actions.

Medium Term:

- Until now, the COTAS lack a reliable source of information regarding groundwater extraction and an easy way to compare it to the concessioned volumes. With this platform, the COTAS will have the tool needed to take better aquifer-wide decisions and set priorities about regulation.
- With individual farmers, COTAS and other farming organizations having access to fully transparent information about the "over-extractors", they could organize to demand the water authority to close down the most relevant illegal wells, fine the major "over-extractors" or take other important regulatory and enforcement decisions.
- With proper measurement and regulation of water extraction within an aquifer, there would be a real incentive to acquire more permits using the *water banks* legislation.
- With a growing demand for water permits, water would reach a balance dictated by the laws of supply and demand, where a sustainability limit applies to both. There would be an incentive for reducing waste of water and modernizing to more water-efficient technologies to be able to sell the surplus in the market.

Long Term:

- Since the webpage will publish information about the state of the aquifer and the actualized trends, COTAS and governments can monitor the impact of their actions and be motivated by the tangible results of their efforts. So would do the greater society.

- Once illegal extraction of water is controlled, and wells are regularized, CONAGUA could buy back the water rights from the users in aquifers with deficit and recover the aquifer's sustainability.

4. CONCLUSION

As discussed throughout the article, the problem of aquifer overdraft in Mexico resides in the lack of law enforcement due to the characteristic "invisibility" of groundwater and the tragedy of commons this is prone to provoke. The proposal here presented aims to make groundwater "visible", and give the COTAS, the government and every other stakeholder a tool to access real and transparent information regarding the state of the aquifer and the levels of extraction of farmers. We outline some methods for gathering information and to present information, however, it is important to note that some data needed for the development of this platform would come from government agencies independent to CONAGUA such as the Mexican Federal Electricity Commission (CFE). These agencies could be reluctant to release information regarding energy consumption, however, by ensuring proper confidentiality (for electricity use, not water, which is a public good under concession) we could gain their support. The importance of the final policy goal of sustainable use of aquifers must be enough to convince them and bring them on-board.

It is important to note that the expected outcomes mentioned earlier are hypotheses that have yet to be tested, for which we recommend a future study where a pilot platform is developed for a specific water-stressed aquifer that has an already functional program of COTAS and compare the results of the use of the platform to the case of another aquifer with similar conditions where the platform is not in use. Ideally a randomized control trial for farmers to which this information is sent should be compared to a control group to which it is not sent, this would help us to truly gauge the reactions to the provision of information.

At the time we were developing this project, a platform with some of the mentioned characteristics was independently being developed: SIEVA, by researchers of the Mexican Institute of Water Technologies (IMTA). It is similar in that it uses energy consumption to calculate the real water extraction volumes by farmers, however, the main difference between the two projects is the aim of our platform to be used not only by water authorities but by everyone interested, all stakeholders, specifically water users and people suffering from groundwater depletion in order to induce peer pressure, collaborative solutions, and user-based water rights enforcement. Being unidirectional the value of information would be lost. A multi-actor platform is needed to bring about change through multiple channels.

The platform we propose might seem ambitious, and it is true that for its proper performance deep institutional and cultural changes must be simultaneously achieved. However, it is clear that aquifers' sustainability cannot be achieved only by "top-down" surveillance without the involvement of users, nor users can be effective in protecting their resource without the proper support and help from the governmental agencies. These interactions are needed, and this platform provides an optimal tool for their enablement. In the long term, evidenced by the trend towards IT solutions, a platform like this will represent a "must have" for any aquifer-level organization that seriously aims to achieve a sustainable use of its limited resource. It might be hard but not impossible, through a system like the one proposed here, to promote community participation, activate water markets, and eventually draw the path for an authentic Inclusive Green Growth in the Mexican groundwater-based farming.

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