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Soil, Water, Labour
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Water in Agriculture

How Agriculture Pollutes Water and How Local Strategies Can Change It

Julian Häderli, Brandon Schwab Rodriguez, and Tolga Tomel

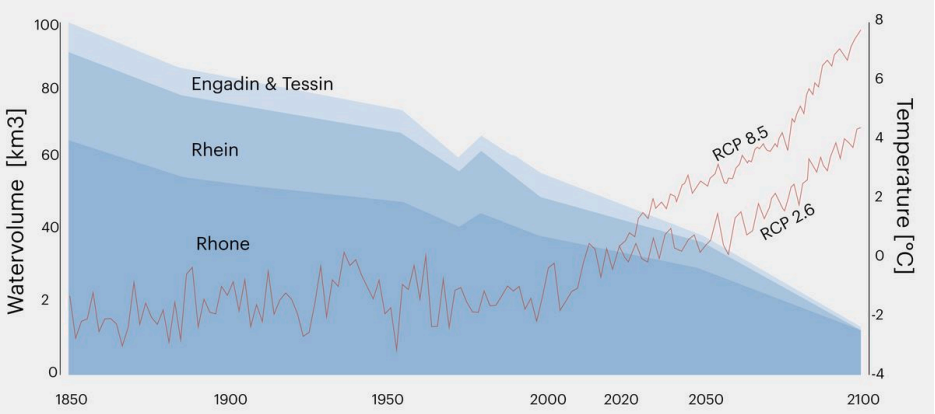


Is Switzerland losing its status as Europe’s water castle? Water resources are being put at risk due to climate change and intensive agriculture. To facilitate a sustainable water balance for the future, requires a combination of new networks of water governance, irrigation technologies, and alternative crop cultures.

Water Source: The Diminishing Swiss Water Castle



A well known fact are the amount of glaciers Switzerland has, meaning the enormous storage of fresh water kept in the ever decreasing ice vault. Different studies and future scenarios indicate that the glaciers will lose up to 90 percent of the volume by the 22nd century threatening the key catchment areas Engadin, Ticino, Rhone, Rhine, and many more. This increasing documented loss of ice volume at the top of the mountains is due to the major impact of climate change.



Decreasing watervolumes in catchment areas

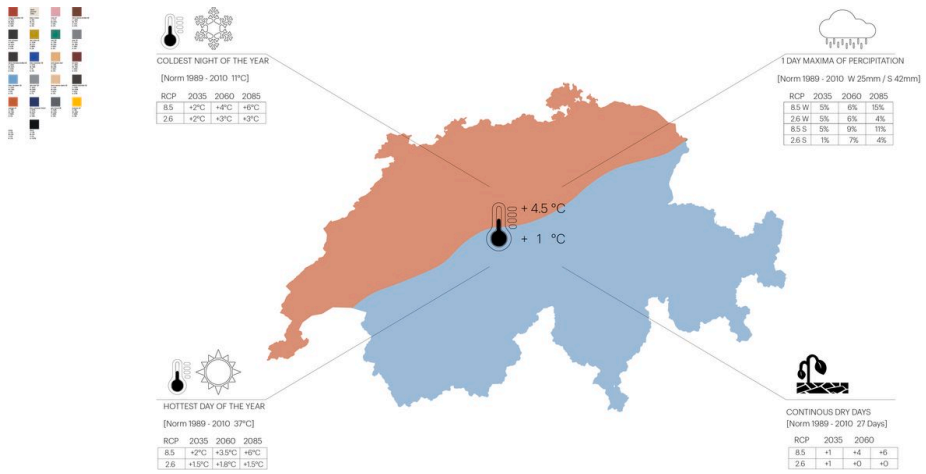
A well known fact are the amount of glaciers Switzerland has, meaning the enormous storage of fresh water kept in the ever decreasing ice vault. Different studies and future scenarios indicate that the glaciers will lose up to 90 percent of the volume by the 22nd century threatening the key catchment areas Engadin, Ticino, Rhone, Rhine, and many more. This increasing documented loss of ice volume at the top of the mountains is due to the major impact of climate change.

The Representative Concentration Pathway's (RCP) 2.6 and 8.5 are only two of many introduced trajectories by the Intergovernmental Panel on Climate Change (IPCC), but they represent opposite poles.

The RCP 2.6 is an optimistic approach of the trajectory requiring the carbon dioxide (CO2) emissions to start declining by 2020 and go to zero by 2100. The CO2 emission has the highest priority, although there are many other factors that need to be decreased such as methane and sulphur dioxide. One of the important factors for decreasing the CO2 emission is focusing on creating a negative factor which can be achieved by introducing an increased area of flora.

In contrast the RCP 8.5 is a trajectory, which is counting on increased emissions throughout the 21st century which will continue to put further negative pressure on climate change.

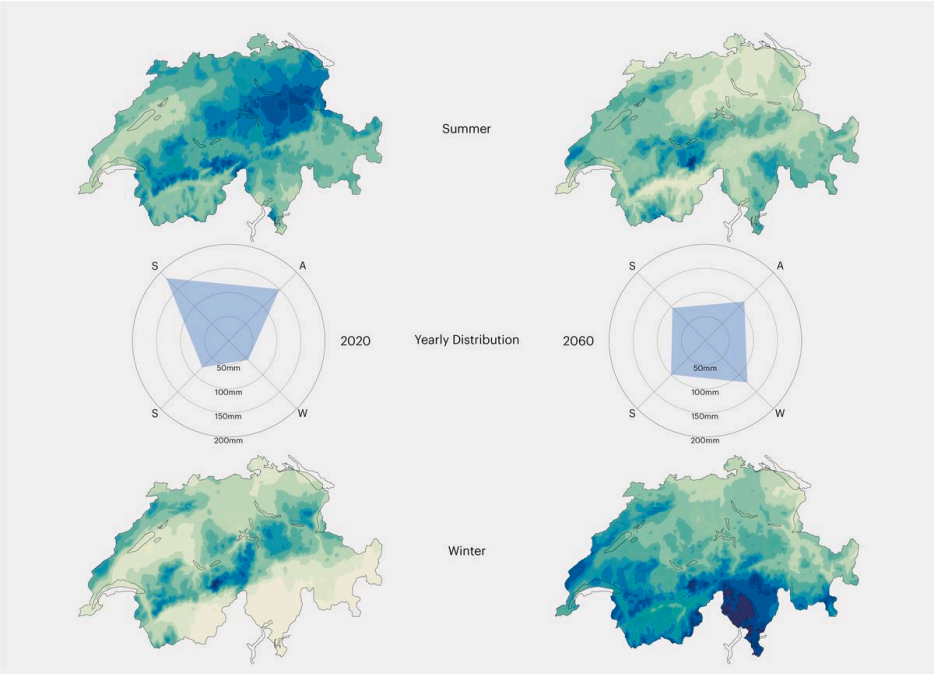
In 2016 many nations signed the Paris Agreement, which is an agreement within the United Nations Framework Convention on Climate Change, with the main focus on improving the greenhouse gas emissions. The long term aim is to keep the global mean temperature increase below two degrees Celsius and reach a level near the pre-industrial times where the anomaly hovered around zero.



Swiss RCP Scenarios show an increase of extreme situations

Switzerland has also made their own studies based on the existing ones and have produced different RCP trajectories for the Swiss territory. Whilst focusing on a smaller area it is also possible to create different scenarios for different climate extremes, thus they have introduced many predictions concerning future changes from 2020 to 2085 and comparing them to the set norm of 1989–2010.

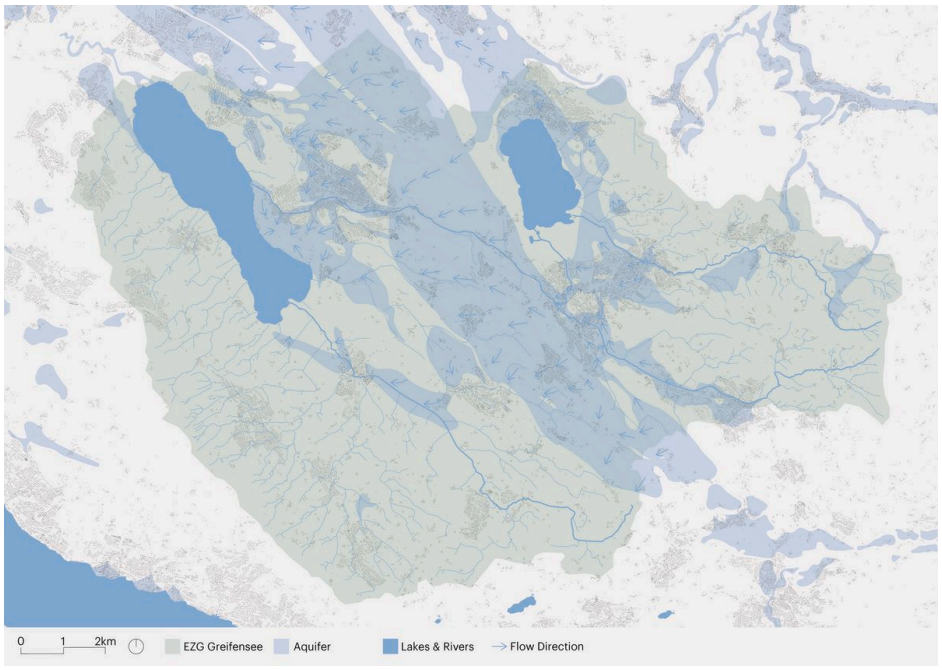
These high level global trajectories and scenarios can also be related to smaller local regions. The Greifensee catchment region in the Canton of Zurich has many different waterbodies. There are three key factors that make the region of Greifensee unique in regards to water in agriculture. First being the fact that the main water supply comes from the groundwater, which flows through the aquifer. Secondly, the agricultural area resting on top of the aquifer and the third factor being the percentage of agricultural surface in combination with the settlement surface, making this a rather compact and multilayered area.



Shift in distribution of precipitation over a year

Comparing Uster, which is the third largest town of the Canton, and the city of Zurich to one another, one can notice the different waterbodies that supply each town. Whilst Zurich provides the inhabitants with mainly lake water and tries to pump as much water back into the aquifer as possible, Uster uses its groundwater to supply water risking its level.

Farmers today are facing ever increasing climate extremes and hence are experiencing longer droughts and a shift in precipitation. The average annual rainfall has not lost its volume, but it has gone through major changes in distribution. On the one hand the rain which falls in summer has become something of a rarity, but when rain does fall it comes in such an extreme causing more damage than good. What also will happen is more rainfall in winter and less in summer forcing farmers to irrigate more to save their crops. When experiencing droughts and having to irrigate en masse the Greifensee region taps into the groundwater and risks the groundwater level to sink further.



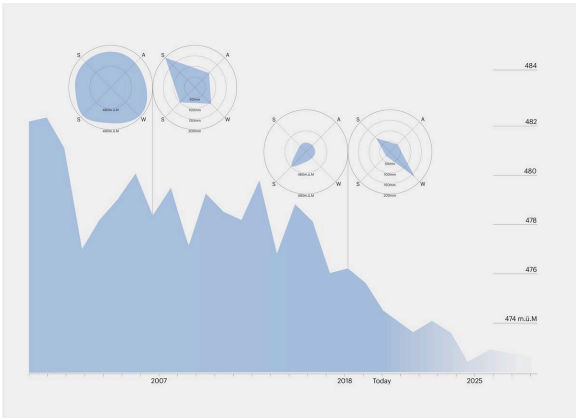
The catchment area Greifensee is characterised by an enormous aquifer as the main water source.

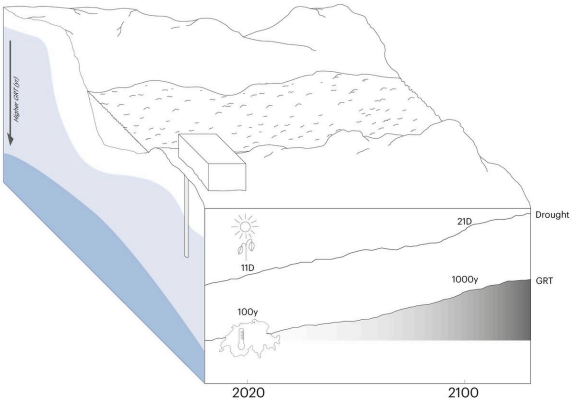
Using the water from the underground has never been a problem, but when experiencing dry years and only having extreme rainfall it cannot recover to the level it once was, which usually occurs through constant smaller amounts of rain. In scientific terms this is called Groundwater Recharge Time (GRT). The monitoring of the aquifer has provided the knowledge of its annual cycle, meaning the fluctuations it has, sinking in summer and recovering in winter. This shows how sensitive the water in the aquifer is and how it is an entity that documents the history of the climate.



Irrigation in extreme situations, Regensdorf. Source: Comet Photo AG (Zürich)

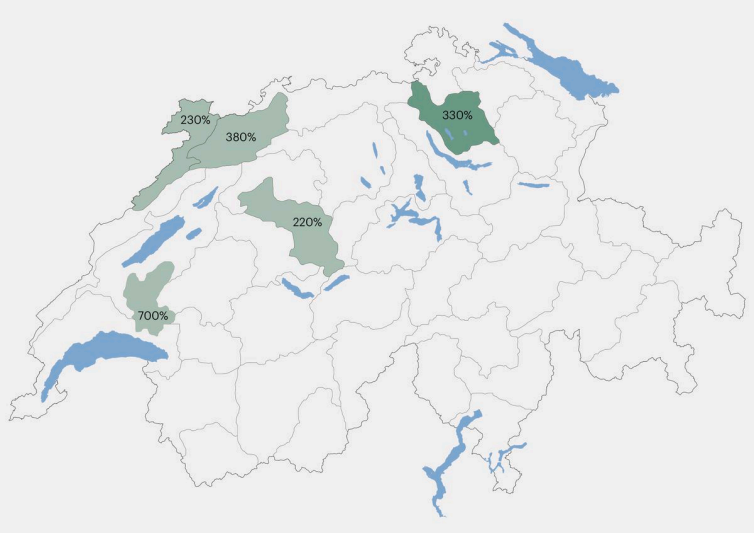
When experiencing a dry year, for example 2018, one of the driest documented years in Swiss history, the groundwater level could not recover in the early winter season of 2019. With the following years not being better than the last, the level has been on a downward spiral ever since causing worry for the community. With knowledge of future climatic developments and the assumption of increased water usage, the groundwater level will continue to sink, generate a longer recharge time and thus casting a shadow on future generations. By 2100, it will take more than 1000 years to make the aquifer accessible again, if the climate change issues are not addressed.





Sensitive groundwater level
in relation to climate change

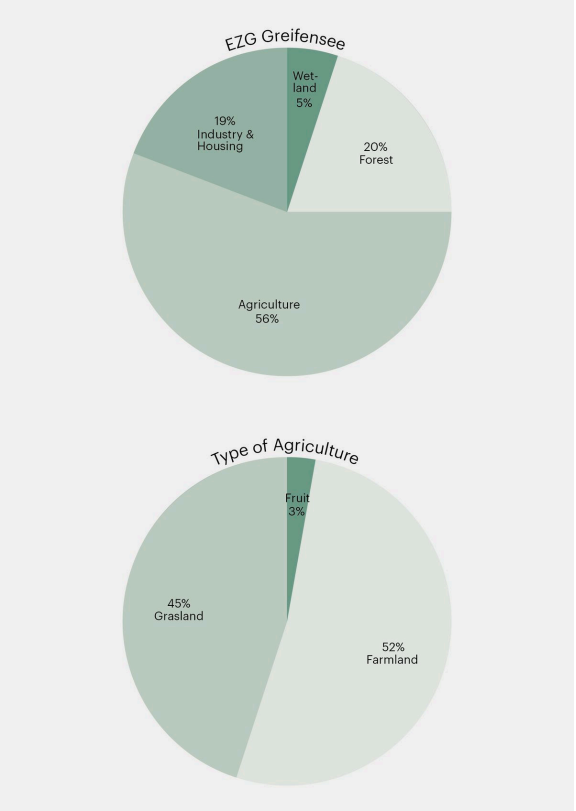
Water Distribution: From Aquifer to Agricultural Fields



Due to increasing temperatures and an increase of water irrigation, it is crucial to know for what the water is being used. When analysing Switzerland and comparing regions to one another, it shows, that the Greifensee catchment region is one of the few that irrigates exponentially more than the rest of Switzerland. The catchment area of Greifensee and the larger region Glattal have a rather high percentage of agricultural land compared to the other regions. With this it is normal that the irrigation is exponentially higher compared to others. This demonstrates how agriculture needs to adapt and become more sustainable for the near future. To get a grasp on the region of interest it is necessary to distinguish between three types of irrigation uses: vegetables, artificial meadows, and agriculture. The last being all farming activities (for example fruit or husbandry) excluding vegetables. All these different categories are sorted by the amount of average water they use to sustain the expected yield.



Irrigation need per type of land use in catchment area Greifensee



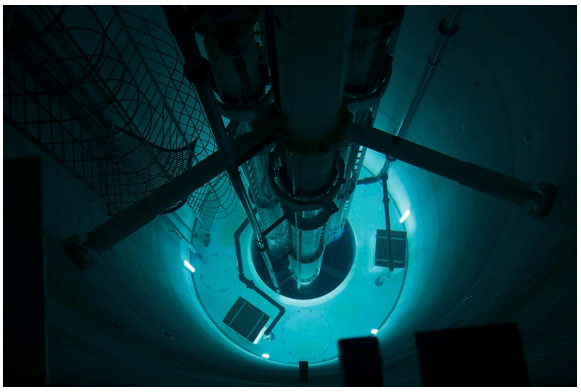
The region of the Greifensee uses only the groundwater, all the other different sources are not consumed or used by the population. No matter what the water is used for, if it is to have a shower, clean the car or irrigate the agricultural fields it all is the exact same quality. The groundwater itself collects water from precipitation, rivers, and the lakes, through the different layers of sediment that provide a natural purifying process ensuring good quality.

Through a system of different pumping stations distributed at many different locations, the water is pumped up by horizontal filter wells. The various pumping stations initially distribute the water into different reservoirs which are located at an elevated area and thus making the distribution dependent on gravity and pressure. This reservoirs are usually located in forests, hidden away and protected from being disturbed. The simple structure on the outside does not give justice to the complexity of the infrastructure behind the door and under the ground.

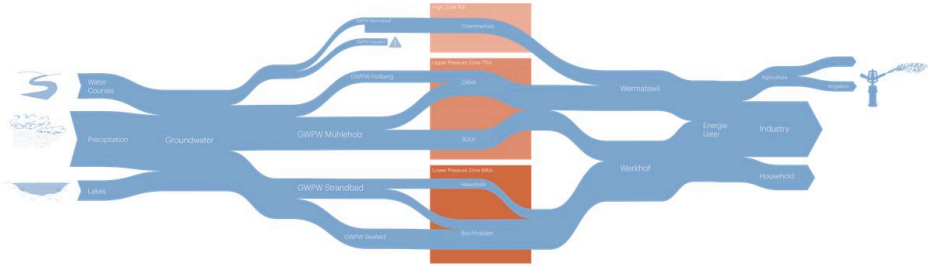
The water quality standards in Switzerland are relatively high and monitored on a daily basis. The Pumpwerk Freudwil however, did not stay under the limit for specific metabolites, which are degradation products of pesticides such as chlorothalonil. As a result, the station had to be shut down temporarily.



Disguised water infrastructure.



Horizontal well acessing the aquifer.

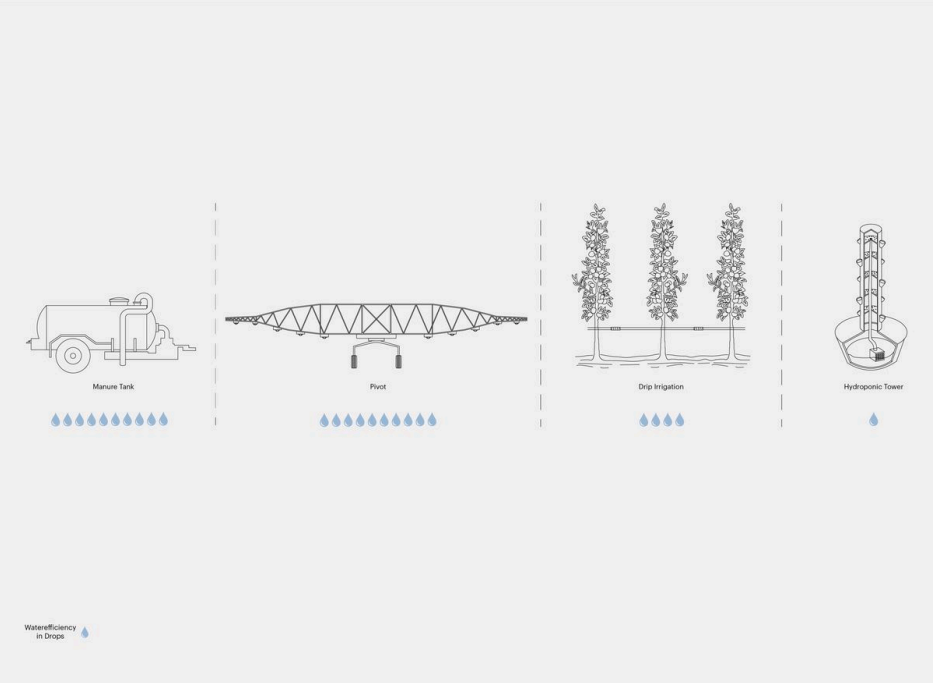


Collecting, storing, and distributing: the path of groundwater from its source to its use.

Irrigation of the Agricultural Field

When researching and speaking with farmers about their particular irrigation methods, it was noticeable which machinery was the favorite. The manure truck was the most popular one, due to its mobility and flexible use. It can be used to fertilise as well as irrigate the field.

The centre pivot proved to be another popular irrigation machinery, as it is relatively cheap and irrigates a larger area very quickly. The centre pivot can also be used for the most amount of crop cultures, due to its height and easy structure. The two described irrigation methods are traditional ones, but also the ones that have a high inefficiency in water usage.



What does your farmer irrigate with?

A newer but not so common method is the drip irrigation system, which is water efficient but does not have the life span of one of the traditional ones nor is it as cheap. The initial set up is expensive, but after the installation it proves to be a more efficient system to run with not too much maintenance needed.

The latest and most unconventional cultivating method is the hydroponic system. This method has been gaining increasing attention and acceptance. Only a handful of farms have tipped their toes into this kind of farming and have showed rather promising results. It is a system that proves to be extremely water efficient and does not require any soil. Additionally, this system can provide an increase of crop, due to its stack-ability in the vertical axis.

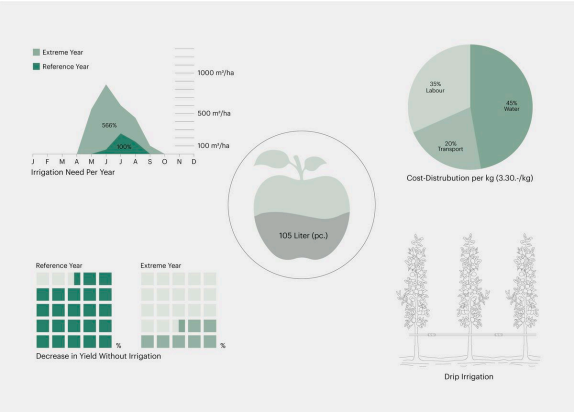


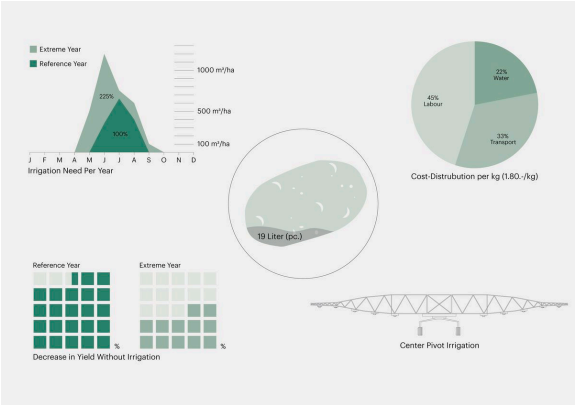
Fishfarm Fisibach, 2020.

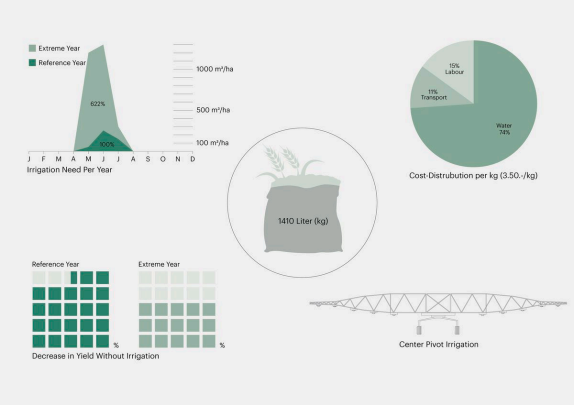


Ortoloco Dietikon, 2020.

When calculating the amount of water flowing into a specific product, which includes everything from irrigation to transporting and storing the term virtual water comes to mind. With increasing droughts and predicted drier years coming the virtual water of these products will rise, begging the necessary question of rethinking what is being farmed. This should be led by societal change in diet, not just by trying to lay off the meat but also being more considerate of what kinds of fruit and vegetables are consumed






Extreme Year
Reference Year
622%
100%
1000 m³/ha
500 m³/ha
100 m³/ha
J F M A M J J A S O N D
Irrigation Need Per Year
15% Labour
11% Transport
Water 74%
Cost-Distrubution per kg (3.50.-/kg)
1410 Liter (kg)
Reference Year
Extreme Year
%
%
Decrease in Yield Without Irrigation
Center Pivot Irrigation

The Impact of Pesticides Leads Us Underground



At this point all the pollutants such as fertiliser and pesticides come into play. Besides irrigation the use of pesticides and fertilisation can increase the yield of the crops. However, the use of fertiliser and especially pesticides is highly controversial and hotly debated. The article from the Tages-Anzeiger (17.9.2020) demonstrates the political topicality but also the missing transparency concerning these substances. The use of pesticides in the Canton of Zurich has even been linked to the death of children.



Tages-Anzeiger – Donnerstag, 17. September 2020 15

Zürich

Was hat ihre Söhne getötet?

Pestizide im Verdacht Im Weinland erkranken mehr als dreimal so viele Kinder an einem Hirntumor, wie statistisch zu erwarten wäre. Zwei Familien aus Flaach, die einen Sohn an die Krankheit verloren haben, fordern Aufklärung.

Mirko Plüss

Innerhalb eines guten halben Jahres schlägt das Schicksal in der Gemeinde Flaach im Zürcher Weinland bei zwei Familien zu. Nach der Diagnose Hirntumor verliert das Ehepaar Kreuzer seinen 14 Monate alten Buben und das Ehepaar Pasanen seinen achtjährigen Sohn. Doch war es tatsächlich einfach nur Schicksal? Diese Frage lässt die beiden Familien nicht mehr los.

Im Februar 2018 vermutet die Coiffeuse Belinda Kreuzer, dass ihr damals neun Monate alter Sohn Max einen Magen-Darm-Infekt hat. Er erbricht auch auf nüchternem Magen und wirkt apathisch. Doch dann kommt der erste epileptische Anfall. «Im Spital haben sie den Tumor sofort gesehen, nur dank einer Notoperation ist Max nicht schon damals gestorben», erzählt Belinda Kreuzer heute.

Monatelang wird versucht, das Baby im Zürcher Kinderspital mit Chemotherapie zu behandeln. Ein kurzer Aufenthalt zu Hause wird jäh unterbrochen, als Max sich mit Windpocken infiziert. «Wir hatten schon auch viel Pech damals.»

Ab Mai gibt es für Max laut den Ärzten keine Hoffnung mehr. «Es war ein absoluter Schock,

Die Familien Kreuzer und Pasanen kennen aus der Verwandtschaft keine vergleichbaren Krebsfälle oder andere Faktoren, die ein erhöhtes Risiko bewirkt haben könnten. Sie schliessen sich zusammen, angetrieben durch Trauer und Skepsis: Was, wenn Umweltfaktoren für den Tod ihrer Kinder mitverantwortlich waren? Was ist mit all dem Gift, das in Pestiziden seit Jahrzehnten auf die Felder gespritzt wird, auch in Flaach?

Mit zahlreichen Fragen konfrontieren sie im Sommer 2019 den ehemaligen Zürcher Kantonsarzt. Und überraschend wurde ihnen für den Bezirk Andelfingen tatsächlich ein erhöhtes Risiko für Hirntumore bei Kindern bestätigt, das damals der Öffentlichkeit nicht bekannt war. Doch ihrer Bitte, das ganze wissenschaftlich zu untersuchen, sei der Kanton nicht nachgekommen.

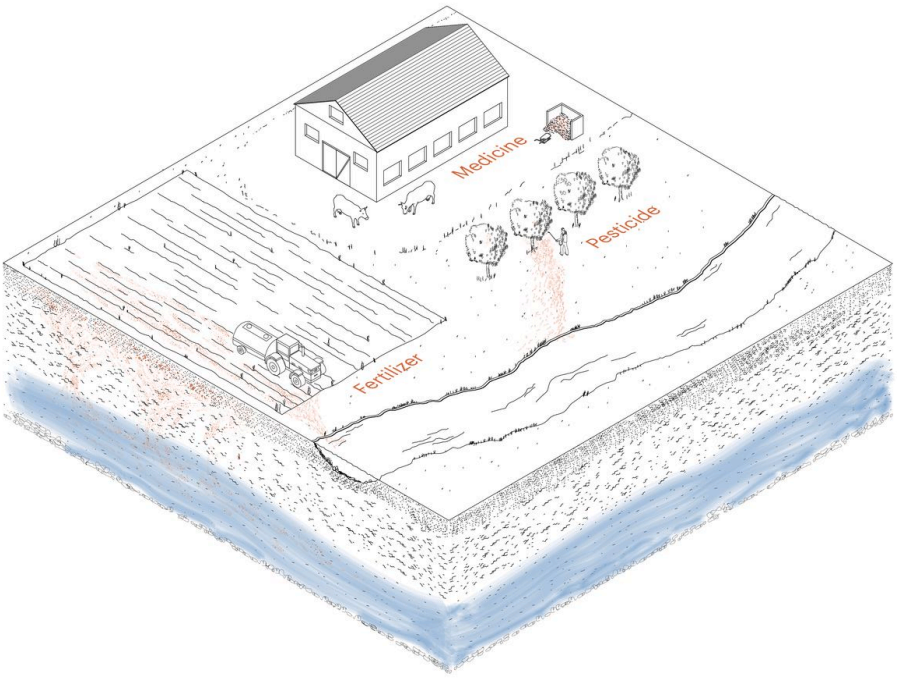
Beim Kanton heisst es im Juli, es gebe keinen Handlungsbedarf.

Tatsächlich listet ein Dokument

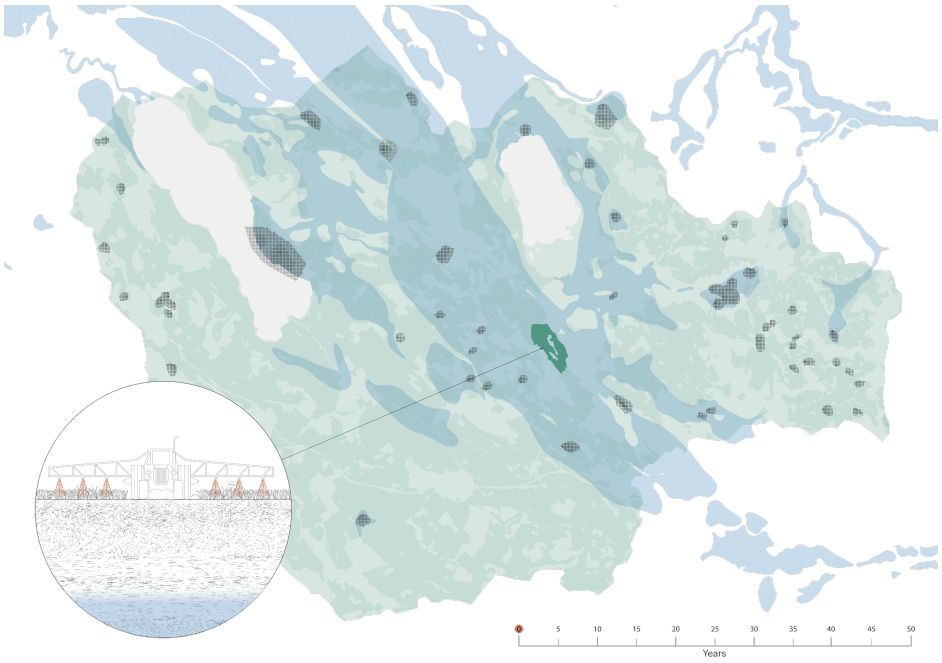
Sohn Max starb mit 14 Monaten: Die Familie Kreuzer vor ihrem Haus in Flaach. Foto: Madeleine Schoder

«What has killed their sons?», Tages-Anzeiger, 17.9.2020.

In this chapter we differentiate between the three main water pollutants of agriculture which are pesticides, fertiliser, and vet medicine. These matters reach the watercourses in different ways such as by drift, surface runoff or drainages. Additionally, a part of the applied substances seeps through the soil and reaches the aquifer.



Multiple ways in which agriculture pollutes different water bodies.

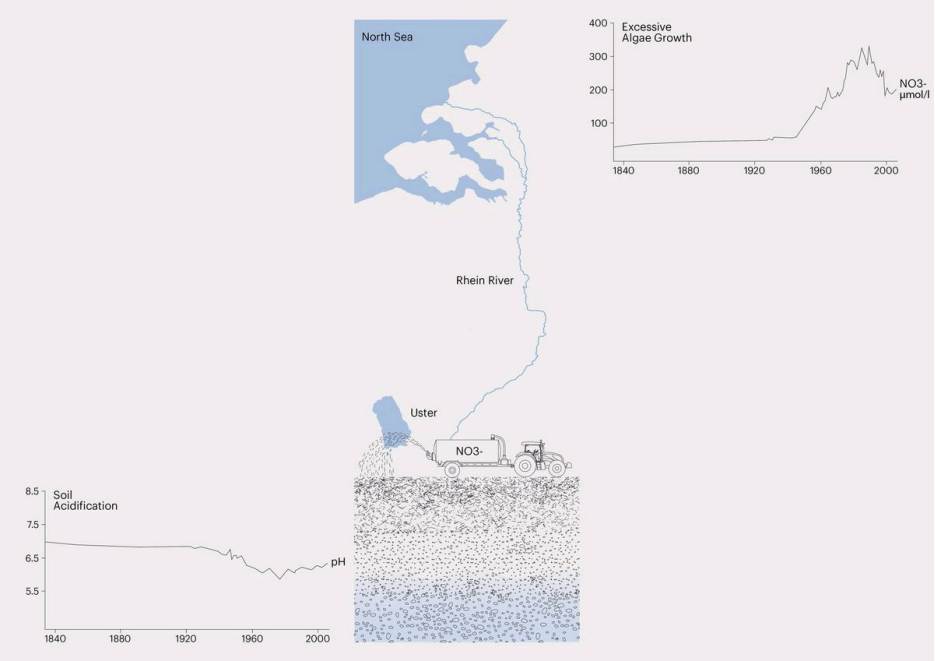


The slow flow of substances in the aquifer.

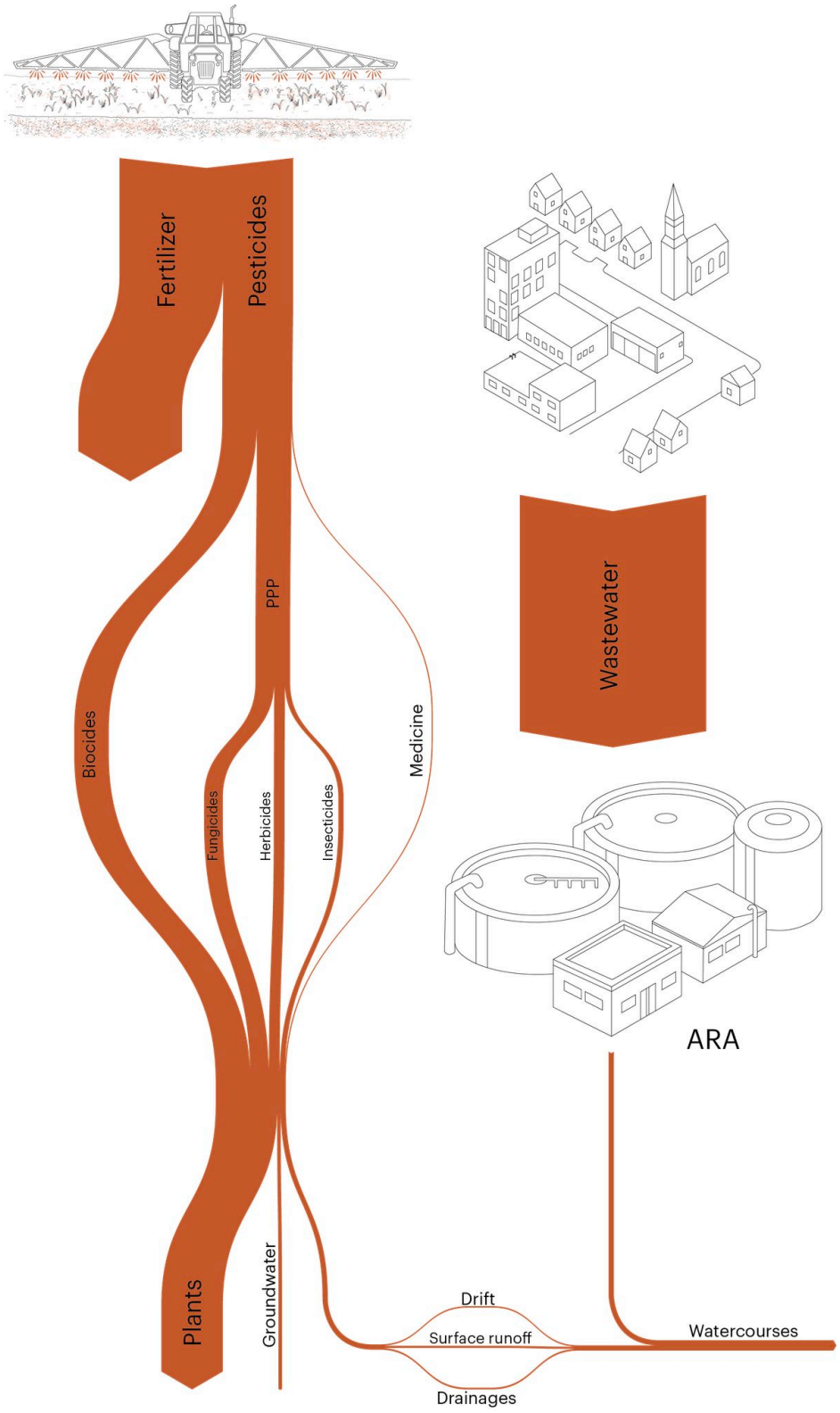
When focusing on the groundwater, it is crucial to understand the time horizon and manner in which the pollutants travel in the aquifer. The groundwater reservoir is technically also a big river, it just flows at a much slower rate. Meaning that pollutants which have been applied at one point in time, can stay in the aquifer for decades to come. Even the prohibition of application of any form of pollutants in the protection zones, does not save the pumped up water from been contaminated.

The first big issue in agriculture is the over-fertilisation and it can be seen as mostly an ecological problem. Large amounts of the applied fertiliser reach the watercourses or seep into the aquifer, which leads to a drastic increase of nitrate concentration in the rivers, lakes, and the groundwater. Locally, this can lead to the acidification of soil.

Furthermore, nitrate is extremely stable and it is difficult to remove from water bodies. On account of that, the locally contaminated water reaches the Rhine and the nitrate finally spills into the North Sea. There it leads to the overproduction of certain species of algae which endanger the ecosystem. So not only does the over use of fertiliser affect the region of Greifensee locally, but it also has a continental impact on the environment.



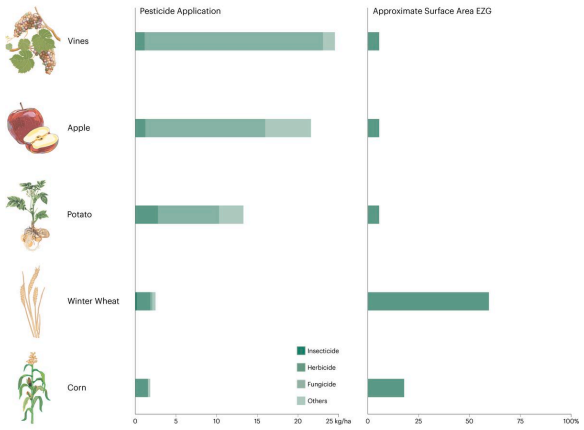
Local and continental impact of overfertilisation due to the transportation of nitrate in rivers.



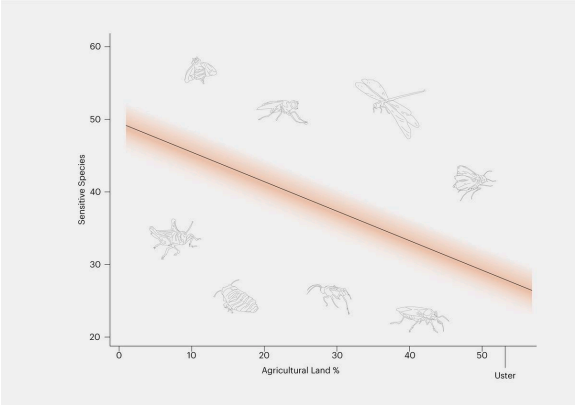
A precise look at the different agricultural pollution in comparison to the urban wastewater network.

The second issue is the application of pesticides, which is explored more thoroughly in the coming part. Compared to the over-fertilisation, it affects primarily living beings.

When comparing settlements and the industry, all the substances applied by the farmer directly reach the soil and thus the groundwater. Meaning there's no barrier, like the waste water treatment plant (ARA), between the application of pollutants and the watercourses.



Application of different pesticides heavily depends on crop culture



SPEAR index: agriculture impacts number of invertebrates in rivers

It is however important to mention that a large part of the applied pesticides are absorbed by the plants and only extremely small amounts reach either the groundwater, or the rivers and lakes. Yet even these minor quantities are a significant problem. Moreover, the amount of pesticides applied varies greatly with the plant culture. While vines and apples are generally pollutant intensive, crops like wheat and corn require less pesticides to maintain a high yield.

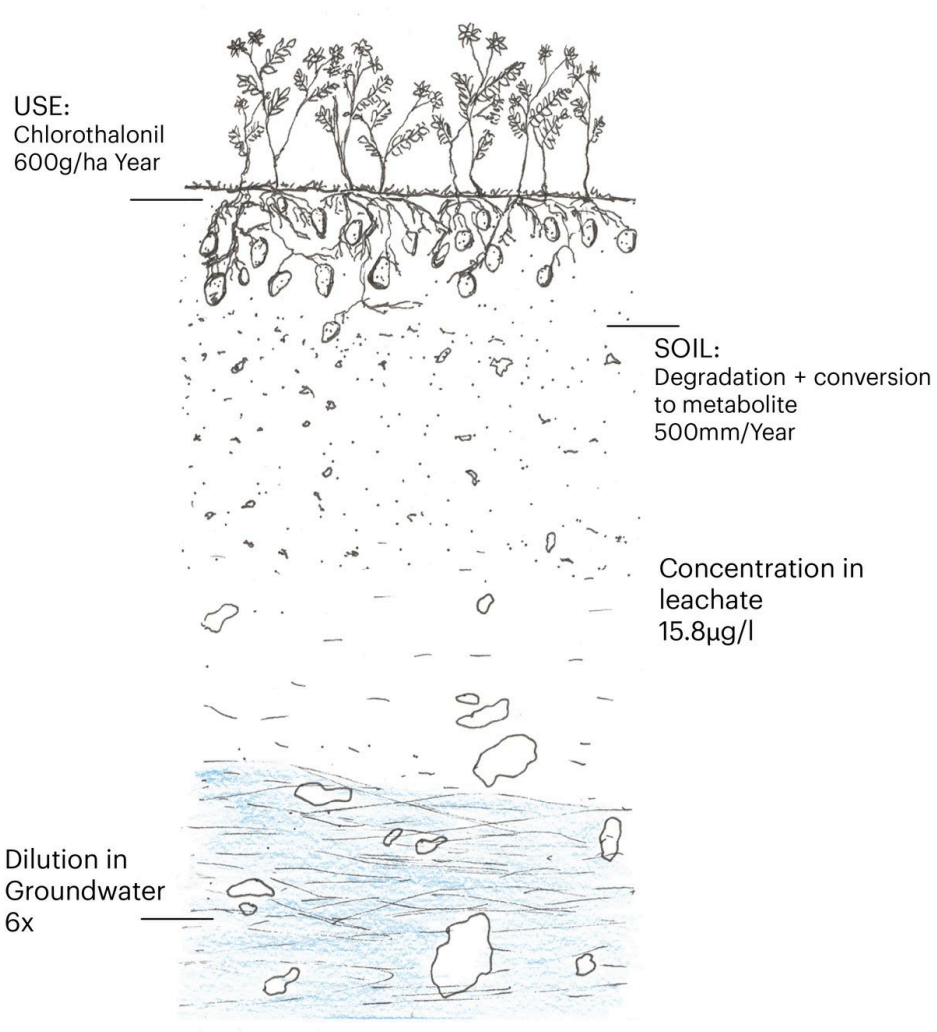




Pesticides impact both above as well as below ground watercourses.

Pesticides have an impact on both the above ground as well as on the below ground water courses. Firstly, the small amounts of pollutants that reach the rivers, endanger their biodiversity greatly. The SPEAR index tells us that the number of invertebrates proportionally reduces with the share of agricultural land in a region. Since the catchment area Greifensee consists of mainly farmland, the diversity in rivers is accordingly low.

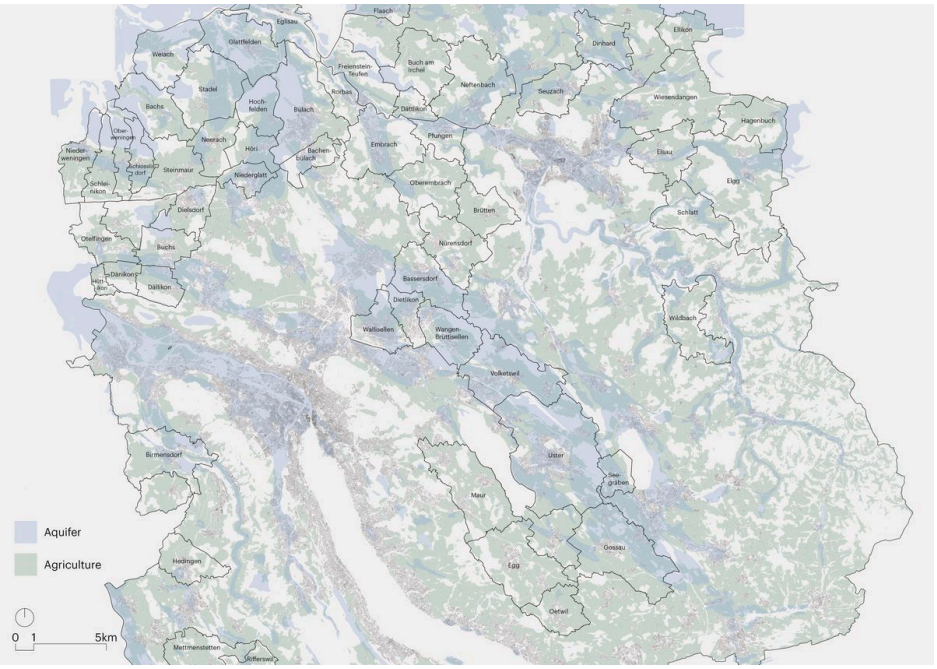
The impact of pesticides on the underground is not as simple to define, as not the substances themselves but rather their metabolites are the issue in the groundwater. Metabolites are the degradation product of the primary applied pesticides, such as chlorothalonil, which are converted by the soil. Therefore, the type of soil is decisive for how long these metabolites stay a problem in the aquifer. On one hand it depends on the sorptive capacity of the soil, so how long the metabolites are stored. On the other hand it is dependent on the infiltration capacity, meaning how fast water can seep through the soil. Combined they are the measure for the time horizon in which the soil emits metabolites into the groundwater.



Use of chlorothalonil: the course and concentration of the pesticide and its degradation product.

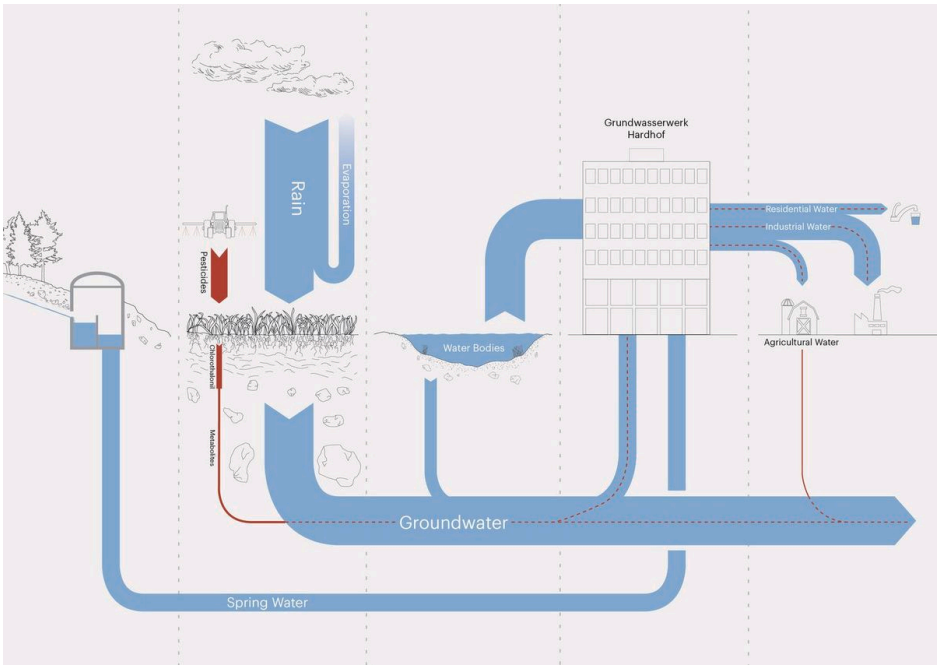


Type of soil is decisive for how long pollutants pose a risk to watercourses



Municipalities that exceed contamination limit of chlorothalonil.

The water is back in the cycle, but is now contaminated. It is pumped up by the groundwater stations and consumed as drinking water. As a matter of fact, the exact impact of polluted groundwater on human health is not yet clear and experts are still undecided. Contaminated aquifers are however a problem in certain areas of the Canton of Zurich. Additionally, several pesticides, including chlorothalonil, are classified as carcinogenic. This would link back to the article previously mentioned. Lastly, the impacts of climate change are also an issue, since a low groundwater level means the concentration of pollutants is higher.



Unseen pathway of chlorothalonil in our water network. Pesticides affect us more than people think.

Supporting Local Water Resilience



As we are now aware, a wide variety of influences on different scales are impacting the water balance in Switzerland today. The reasons for taking action against the increasing risk of water scarcity and loss of existing resources are growing. Different discussions range from philosophical to very technical approaches.

Why can our current water consumption patterns not work in the long term?

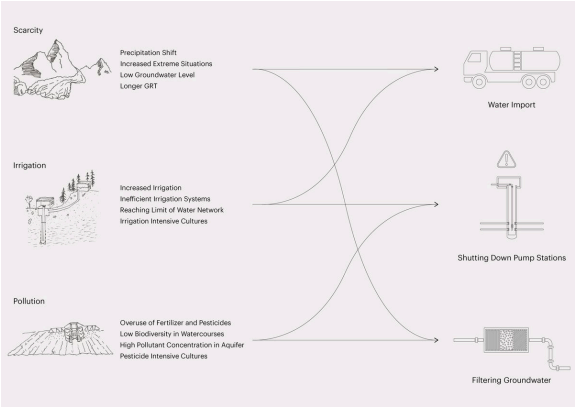
Due to today's way of life, the water balance is directly and indirectly under great strain. Already now we are forced to take certain measures to compensate for smaller shortcomings in the water balance. However, in the long run, these solutions are neither sustainable nor suitable for the large-scale use.

Water shortages, which occur due to global warming and inefficient irrigation, are nowadays attempted to be solved with urgent water imports. However, neither the advancing climate change nor the increasing irrigation needs of current agriculture can be compensated with water imports. On a smaller scale, the consumerism of society and its way of life exerts a lot of pressure on agriculture. The aim is to achieve the highest possible yield on the smallest possible area, neglecting other aspects that play a very important role in the long term.

Yield-increasing methods such as supplementary irrigation or the use of pesticides can lead to a collapse of the water system at certain points. Some water pumping stations are already out of service and if this continues, we will be forced to shut down more water pumping stations for health and environmental reasons and lose other resources. Singular technical aids cannot be the right approach to preserve a sustainable water balance. In order to prevent such non-adapted temporary solutions in the first instance, the policy should be to react less and act more.



Location of the Tumigerhof: the contact of waterbodies with excessive agricultural land.



Why do we have to act? Link between scarcity, irrigation, and pollution

Regarding the agricultural aspect of water management, we focused on the local Tumigerhof farm in Uster. It is located between the municipality of Greifensee and Uster. The site of the Tumigerhof is of great importance, on the one hand because of its proximity to a very large groundwater reservoir, and on the other hand because of its position next to the lake Greifensee. Furthermore, the Tumigerhof lies next to a small hamlet from which it seems to be completely detached.

Various fruit crops are conventionally cultivated in the region around lake Greifensee. Livestock is also raised on the twenty-seven hectares of land. Different infrastructures for irrigation and fertilisation are used on the farm. The proximity to groundwater and other important waterbodies raises many questions about special rules and regulations. Nevertheless, the Tumigerhof does not differ from other farms. On the Tumigerhof, orchards are conventionally treated with fungicides and fertiliser, and it is believed that everything is either absorbed by the plants or decomposed by the time of the harvest. During dry periods, the crops are irrigated with a reused manure tank.



Case Study Tumigerhof



Case Study Tumigerhof



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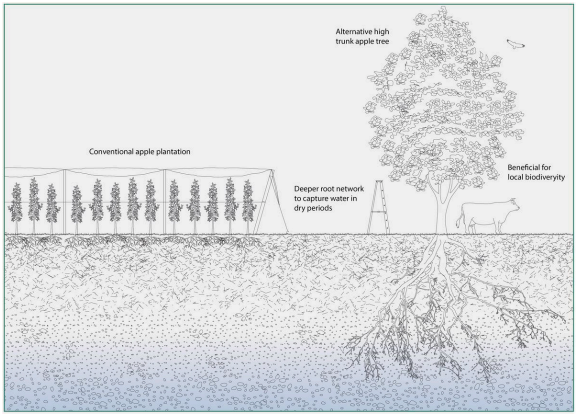
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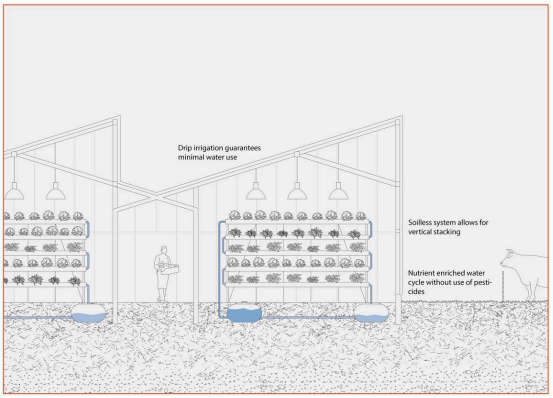
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Toolbox

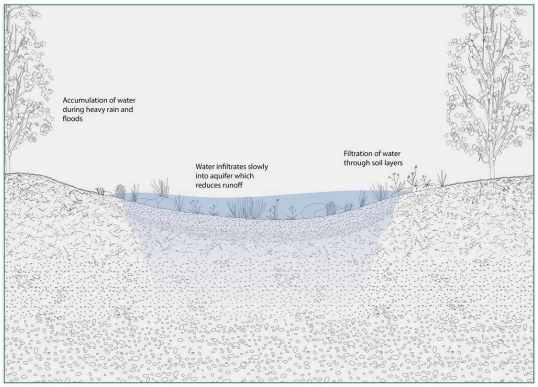
Only by combining several approaches we are able to impact the current situation. In order to do that, we created a toolbox containing three nature focussed solutions as well as three infrastructural and technical tools. We believe that both are necessary in order to balance each other out and facilitate a resilient water cycle. Each of our tools is based on an existing and proven solution. The first natural tool focusses on the cultural shift to high trunk trees. Not only are they more resistant to droughts and pests due to their deep root network, but they also offer a habitat for many different species. Thus the need for irrigation and pesticides is reduced. Rain gardens are the natural equivalent to storm water basins. They collect water during rain and reduce runoff. That way, the captured water can slowly infiltrate into the aquifer instead of washing away on the surface—meaning that the groundwater level can recover even during heavy rain. Lastly, silvoarable agroforestry is introduced to create a safety net beneath the earth surface. Instead of seeping into the groundwater, pesticides and fertiliser are absorbed by the roots of the trees. Moreover, water is kept closer to the surface which reduces the need for irrigation.



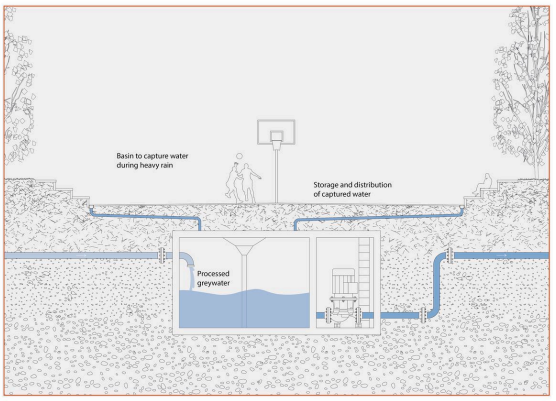
High trunk trees



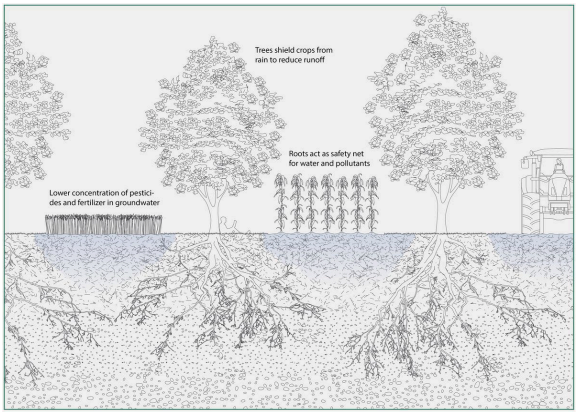
Hydroponic irrigation

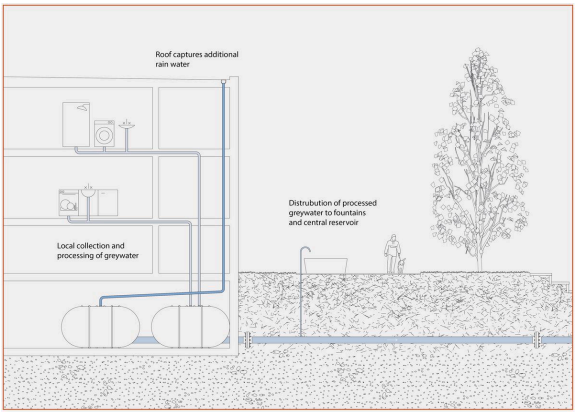


Rain gardens



Stormwater basin





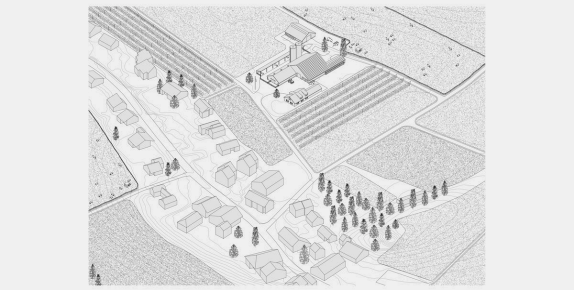
Greywater processing

Complementing the first tools, we furthermore implemented three infrastructure based solutions. The first tool is the hydroponic irrigation. It primarily solves problems concerning irrigation needs as well as the use of pesticides. This system can be retrofitted to existing farms or built as a new greenhouse. Secondly, stormwater basins are a way to capture and use water during heavy rainstorms. Not only does this reduce the risk of flooding, but it also allows communities to store and redistribute the water. Besides that, they function as social spaces for the respective communes. Together with the basin, the grey water processing (Water Hub, Eawag) creates a local water network and leads to new forms of water governance. Once the grey water is processed, it is either used in situ or distributed to farms in need of water for irrigation. However, it is important to mention that the law does not yet allow the use of processed grey water for irrigation. Hence, this political hurdle would need to be addressed.

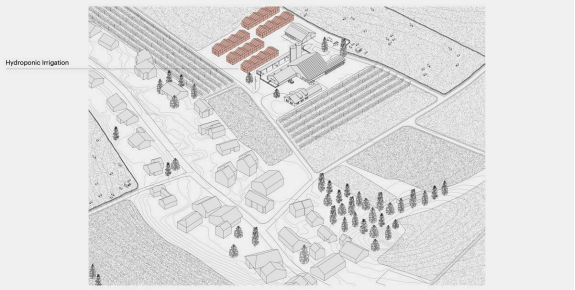


Creating a balance between nature and infrastructure.

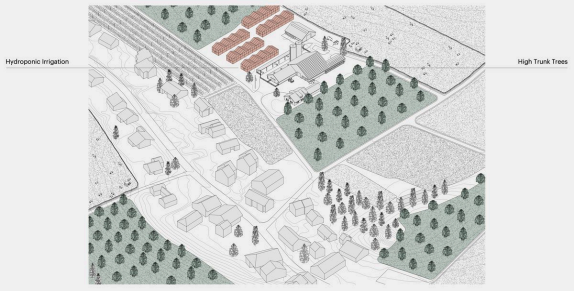
Combining these tools together and projecting them into the given environment of the Tumigerhof, we can experience a drastic change in the appearance of the landscape. High trunk trees and rain gardens create an open atmosphere for production and leisure, while the stormwater basins give the communities a new centre.



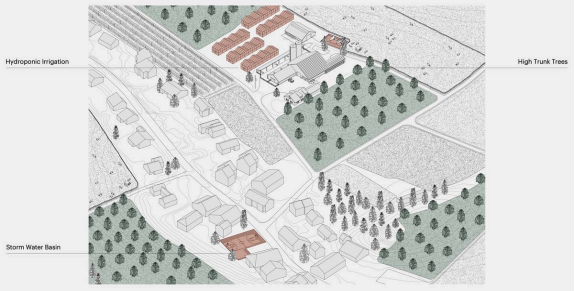
Change of landscape by implementing tools into existing environment of the Tumigerhof.



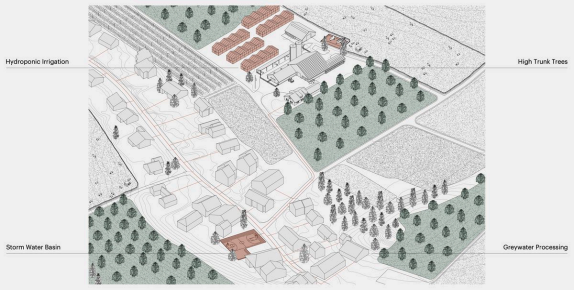
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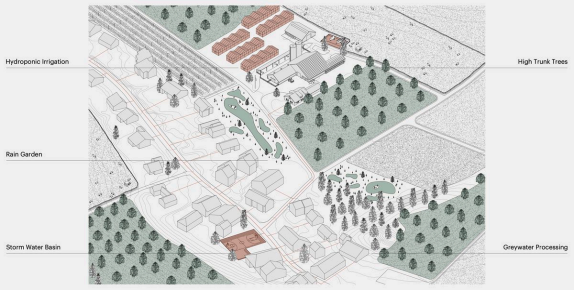
Change of landscape by implementing tools into existing environment of the Tumigerhof.



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Change of landscape by implementing tools into existing environment of the Tumigerhof.

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