Earth to Earth: Reconciling Earthen Dwellings with Eroding Loess Landform
The Case of Loess Plateau in China

by

Bin Li

B.A. (Architectural Studies)
University of Hong Kong, 2009

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
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ABSTRACT

Ten percent of the earth's land surface area is covered with loess deposits, a type of highly erodible soil consisting of less than 20% clay. Loess soil has topped eroding hills and valleys and supported an earthen construction tradition in loess landform territories. The Loess Plateau in China has been suffering from heavy soil erosion. Soil erosion is caused by the scale of the hill and valley watershed and exacerbated by the scale of earthen dwellings. These dwellings are mostly populated by low-income agricultural households. They obtain soil resources from exposed loess sections and build dwellings on nearby flat land. This approach increases erosion to both the landforms and the dwellings, and worsens the living quality of the local residents. Nevertheless, considering affordability, environmental load, and soil stabilization, local soil and natural fiber are good choices of building material.

Can earthen dwellings be designed so as not to increase soil erosion but to reconcile their relationship to the eroding landform? Meanwhile, can vegetated landforms be designed to contribute to the built form? If so, how?

In this design thesis, I show that considering the landform and the built form as a whole is the key to resolve the loess soil erosion problem. Vegetation and grading can be designed to extend from the ridge, to the terraced land, and to the gully slopes to control soil erosion. Five new earthen dwelling types can be introduced, according to various degrees of uncontrolled slopes, in order to reduce both exposed soil sections and earthen walls and not exacerbate soil erosion in the future. Settlements can be upgraded as a result of negotiation between the landforms and the built forms. Such a settlement can triple the number of households to help meet the demand for replacing decrepit houses and for hosting younger families.

The scaling-in research method from the globe to a single dwelling and the design sequence of landscape, dwelling, and settlement together constitute an innovative approach to addressing a complex problem.

Thesis Supervisor: Miho Mazereeuw
Title: Ford International Career Development Assistant Professor of Architecture and Urbanism

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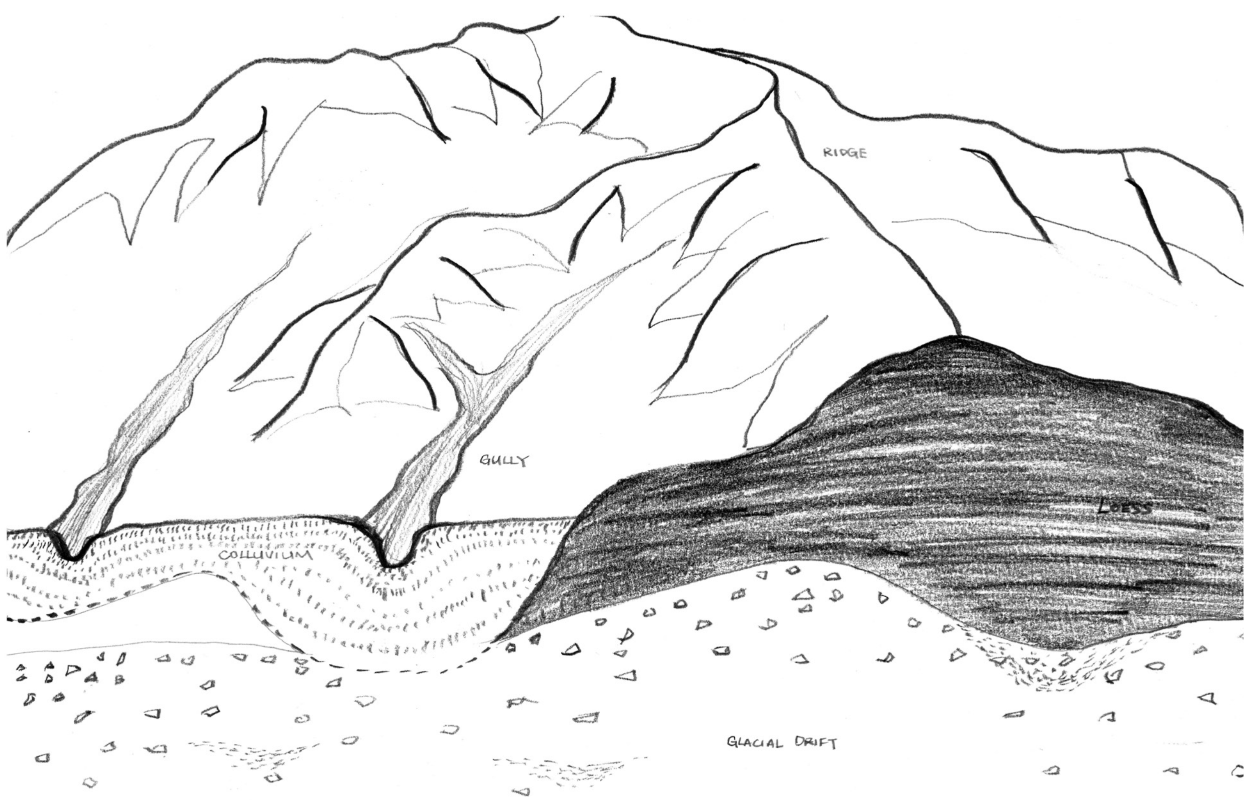


Loess landform sketch (Pencil, charcoal on paper)

Preface **EARTH to EARTH**

In "**Earth to Earth**," the first "Earth" is a landscape term. It refers to the sedimentation, surface processing and landform of a part of the Earth. As we zoom in, we perceive the second "Earth", a construction term. It refers to subsoil raw earth - mud, sand, and gravel - and topsoil plant-based materials as building materials. Earth creates the opportunity for us to dwell, and bridges our dwelling to the environment.

The environment of an earthen house has always been linked with the landscape of a river, its sediments, and agriculture. Geological configuration of raw earth influences the construction technique - rammed earth, adobe, or cob - tying earthen houses closely to the landscape, water, air, minerals, subsoil, vegetation, gravity, and sweat of labor, in which are embedded richness and subtlety.

The expressive subtlety of an earthen house - material, tactile, inhabited by space and light - awakens our senses. It evokes our desire of being in everyday life and projects everyday living into the house. An earthen house records the environment. Its sensitivity to water, wind, plants, everyday life, and aging transforms in silence, inducing the inhabitants to take care of it like taking care of a moss garden. The dwelling lets its inhabitants dwell, while it lives together with its inhabitants.

Through "Earth to Earth," I hope a new lens can be created to make possible a way of looking at earthen landforms and built forms as a whole. Knowledge from geology, botany, mapping, landscape, architecture, and fieldwork is merged along the journey.

Bin Li. May 22, 2014. Boston.

Ten percent of the earth's land surface area is covered with loess deposits, a type of highly erodible soil consisting of less than 20% clay. Loess soil has topped eroding hills and valleys and supported AN earthen construction tradition in loess landform regions such as the Rhine, the Mississippi and the Loess Plateau of the Yellow River. The Loess Plateau area has been suffering from heavy soil erosion. Soil erosion is caused by the scale of the hill and valley watershed and exacerbated by the scale of earthen dwellings. These dwelling are mostly populated by low-income agricultural households. They obtain soil resources from exposed loess slopes and build dwellings on nearby flat land. This approach increases erosion to both the landforms and the dwellings, and worsens the living quality of the local residents. Nevertheless, considering affordability, environmental load, and soil stabilization, local soil and natural fiber are good choices of building material. Researchers often see soil erosion as a consequence of deforestation and the deterioration of dwellings as a simple result of poor construction. In reaction, they design landforms and built forms separately. But because the current situation has resulted from a similar approach and soil erosion has contagious effects across multiple scales, designers need to see the landform and the built form as a whole.

Can earthen dwellings be designed so as not to exacerbate soil erosion but to reconcile their relationship to the eroding landform? Meanwhile, can vegetated landforms be designed to contribute to the built form? If so, how?

In this design thesis, I show that considering the landform and the built form as a whole is the key to resolve the loess soil erosion problem. Vegetation and grading can be designed to extend from the ridge, to the terraced land, and to the gully cuts and slopes in a typical hill and valley landform. Herb planting zones, i.e., flax, hemp and jute, can be designed for newly graded gully areas and combined with a mixture of local trees, shrubs, and grasses. Five new earthen dwelling types can be introduced according to different degrees of slopes (from flat land to straight cuts) in order to reduce both exposed soil sections and earthen walls. Soil use for new dwellings can be self-sufficient through digging on the site's footprint to supply building needs. Roofing is built with natural fiber composites, the product of herb fields, to shelter the dwelling and stabilize the landform. The new dwellings will not exacerbate soil erosion in the future. Existing settlements can be upgraded as a result of negotiation between the landforms and the built forms. Such a settlement can triple the number of households to meet the demand for replacing decrepit houses and for hosting younger families.

THE RESEARCH METHOD is based on a continuous zooming in scale, from the global to the territorial, the regional, the sub-watershed, the hill and valley, the settlement, and the dwelling. At each scale, a typical situation is chosen, to make sure the study from landforms to houses is consistent with generic situations.

The global scale looks at loess soil, loess landform, and types of earthen construction on the earth's surface. The territorial scale zooms into the Loess Plateau in China, looking at the climate, loess thickness, soil erosion, income, and house affordability of the territory. The regional scale zooms into an upstream area where soil erosion starts and a hill and valley landform pattern is legible. Zooming into a local sub-watershed, the ridge, the terrace, and the gully landform features become legible. At the hill and valley scale, the evolution of gullies and settlements reveals that settlements at the head of gullies exacerbate the growth of gully branches. The erosion effects can be seen at this scale mainly as gully erosion, in which the loss of soil volume can be converted to build 60 dwellings per year. At the settlement scale, the uphill-gully type presents a sparser layout while the downhill-valley type presents a dense layout. The former helps to make more gully branches while the latter help to make existing slopes steeper. At a single dwelling scale, the immediate connection of the landform and the built form is conveyed. The subtraction of soil cliff sections becomes the accumulation of dwelling walls. The more houses needed for a household, the more exposed sections are made to supply the building need. From the globe to a dwelling, the research demonstrates coherent causes and effects of soil erosion. The soil erosion problem cannot separate the landform and the built form, which forces designers to look at the land and the built form as a whole process.

FIELDWORK played a significant role in the research process. A field trip to Gansu and Ningxia, the western Loess Plateau, was made in March 2013. Soil and straw samples were collected from the region. Observation of the hill and valley landforms covered fifteen village groups. Thirty households were interviewed.

THE DESIGN METHOD starts with choosing a generic hill and valley site. Vegetated landforms and dwelling types are designed first. Construction system is generic to all building types. The settlement is designed to negotiate the two.

The design principles for the vegetated landform include using local plant species, creating both belt and mix zones, locating herb fields, and planting from the ridge to the valley. It aims to slow down soil erosion process at the scale of hill and valley. Design actions involve grading steep cuts into stepped slopes, planting tree species on the ridge and the steep gullies, shaping gully edges into meadow slopes, and creating herb fields in the gully/valley basins.

The design principles for the dwelling types include reducing exposed loess section, reducing exposed dwelling wall, and making soil supply self-sufficient. The flat type is designed for a piece of flat land, digging down 1.5 meters and building up. The shallow slope type is designed for slopes between 1:3 and 1:2, digging into the slope, retaining the interior, and building the roof. The medium slope type is designed for slopes between 1:2 and 2:3, digging into the slope so that part of the dwelling is embedded into the slope with an arched structure and part is built with roofing. The steep slope type is designed for slopes between 2:3 and 1:1, with the dwelling fully embedded into the slope. The step type is designed for cuts steeper than 1:1, grading the cuts into stepped slope and building on the steps. For all five types, the digging geometry, building geometry and roofing geometry become relatively independent, which gives flexibility to the built form and the landform. Meanwhile, each type can iterate different geometrical and spatial versions.

The construction system of a new dwelling type has three main parts: retaining wall/vault by compressed earth brick (CEB), façade wall by rammed earth, and roofing by fiber/straw composites. A combination of flax mat and clay plaster is used for interior finishing. Straw mats and low-fired bricks are used for exterior finishing to slow down façade erosion.

The settlement design brings the principle of the vegetated landform and the dwelling types together. The pilot design is the first uphill-gully settlement, the starting point of soil erosion in a gully area. With five households living in the settlement, the landform of the settlement area had been gradually changed into cuts and gullies. The settlement can be upgraded by adding ten more dwellings. Those new dwellings can grade the slopes on their footprint and guide the vegetation strategy for the surroundings. For example, the courtyard of the step type can extend to the stepped terrace, in which flax planting can continue. The irrigation channel around the flat type can extend further and connect to the drains of other types. These drains link to agricultural fields to slow down the process of water loss. Eventually the new dwelling types will replace the old five dwellings. Community spaces and gardens can be formed.

THE VISUAL PRESENTATION METHOD involves both analog and digital techniques for drawings and models, including pencil/charcoal drawing, photography, watercolor, ceramics, collage, GIS and Google converted modeling, 3d printing, and CNC milling. Each representation technique aims to fit the information needed to present at a specific scale. The landform features, landform sections, settlement patterns, and the dynamics of the existing dwellings are more precisely presented by pencil/charcoal drawings than computer drawings because the dynamics of landform should not be presented with a firmed boundary line. CNC milling simulates the digging motion into the slopes, while 3d printing presents the idea of accumulated building process. The model making principles are coincided with the building principles in reality.

The research method is a zooming-in process, combining literature review and fieldwork. The design sequence starts with the landform scale and the built form scale, and meets in between. The visual representation methods aim to be precise to each scale by using multiple media. This is an innovative approach to addressing a complex problem. (Bin Li.)

15,000,000 km^2
= 3900 km x 3900 km

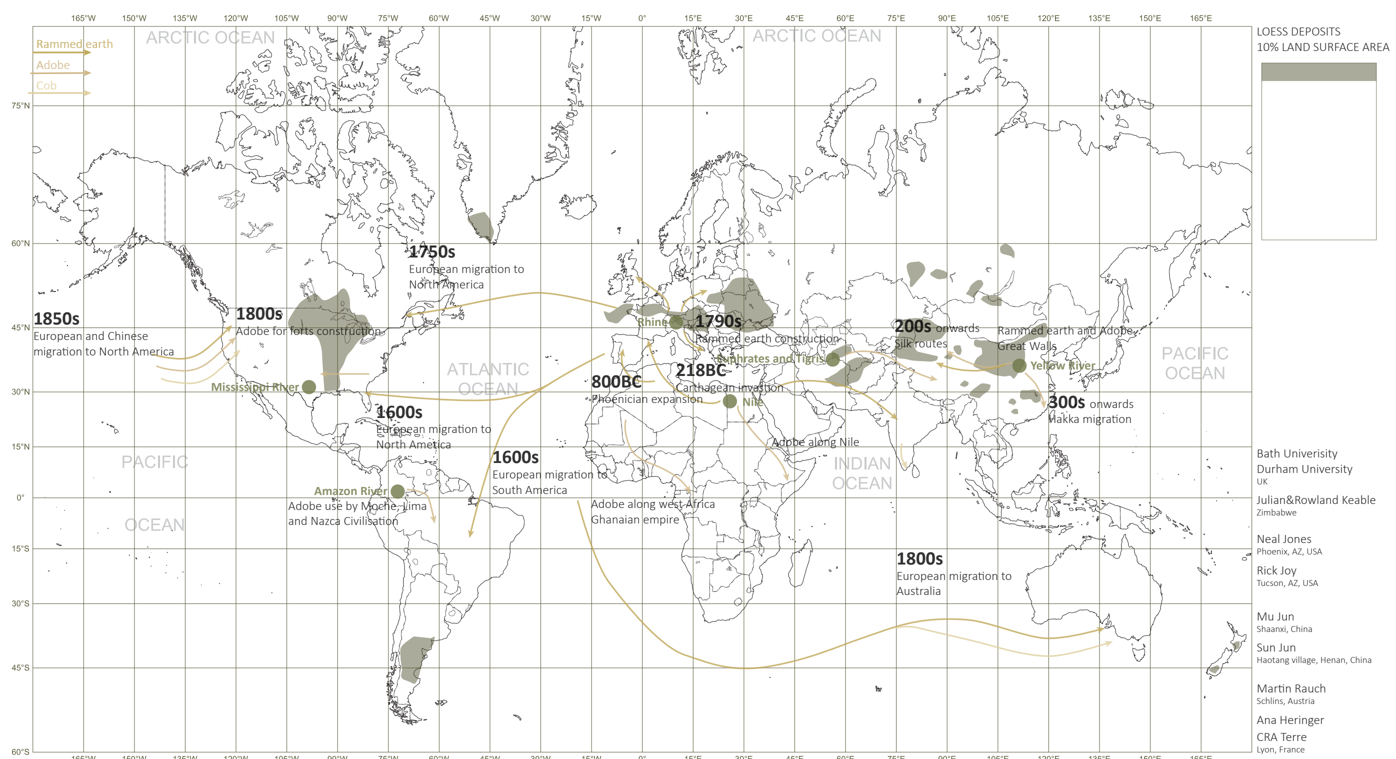
Ten percent of the earth's land surface area (15,000,000 km2) is covered with loess deposits, a type of highly erodible soil consisting of less than 20% clay. Loess soil has topped eroding hills and valleys and supported an earthen construction tradition in loess landform regions such as the Mississippi, the Rhine, and the Loess Plateau of the Yellow River.

Topsoil is the upper layer of soil, the top 5cm to 25cm. It has the highest concentration of organic matter and microorganisms and is where most of the Earth's biological soil activity and agriculture occur. Topsoil material refers to material and product as result of agricultural activities which happen on topsoil layer. These material and product, especially stalk and natural fiber (jute, hemp and flax), are able to apply to building construction process.

Degradable subsoil materials are classified via the size of the particles. They need to be mixed in various ratio –the ratio of clay, sand and gravel - to perform from structural stiffness to surface rendering. Partially-degradable earthen materials – bitumen, trass lime and low fire tile – are used for construction. Cement is generally not encouraged because of the high embodied energy for producing it.

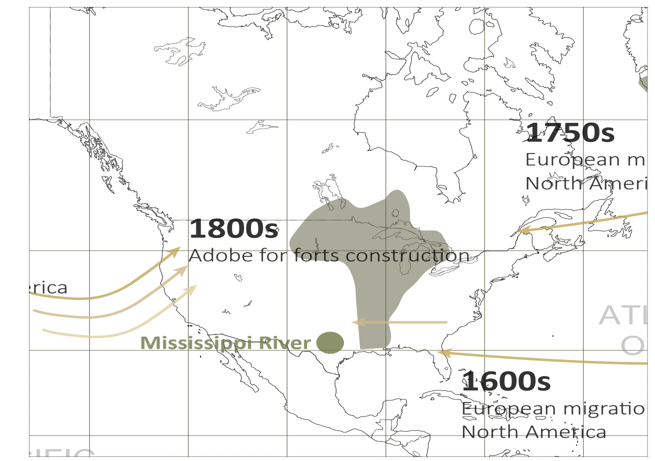
Cob, adobe and rammed-earth were three major earthen construction methods traditionally.
In modern era, innovated rammed-earth system, compressed earth brick, and natural fiber composites are more promising than the rest.

1.1.1. Loess Land & Built

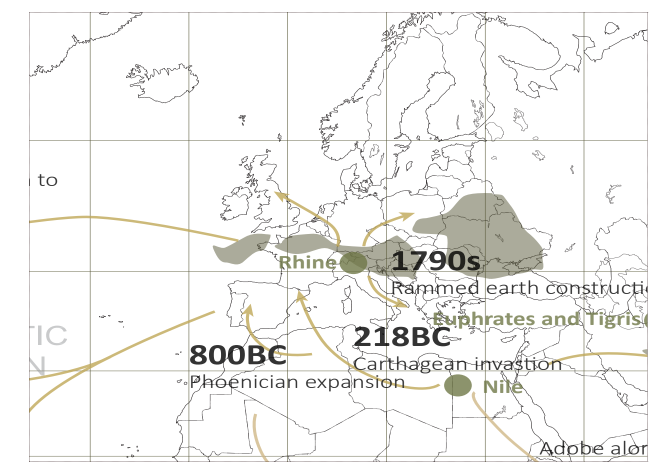


Loess landform and construction world map

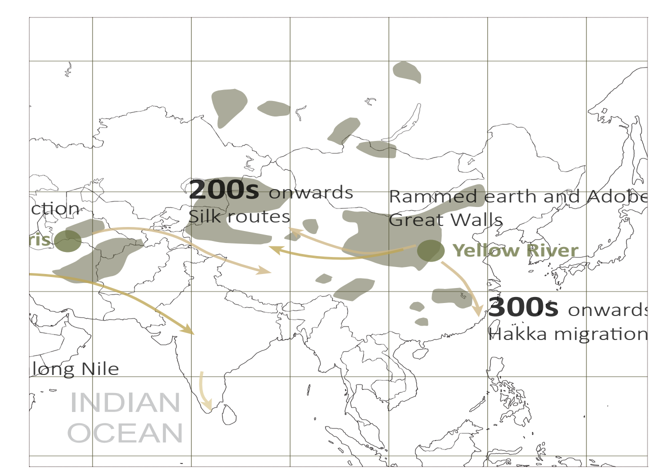
the Mississippi



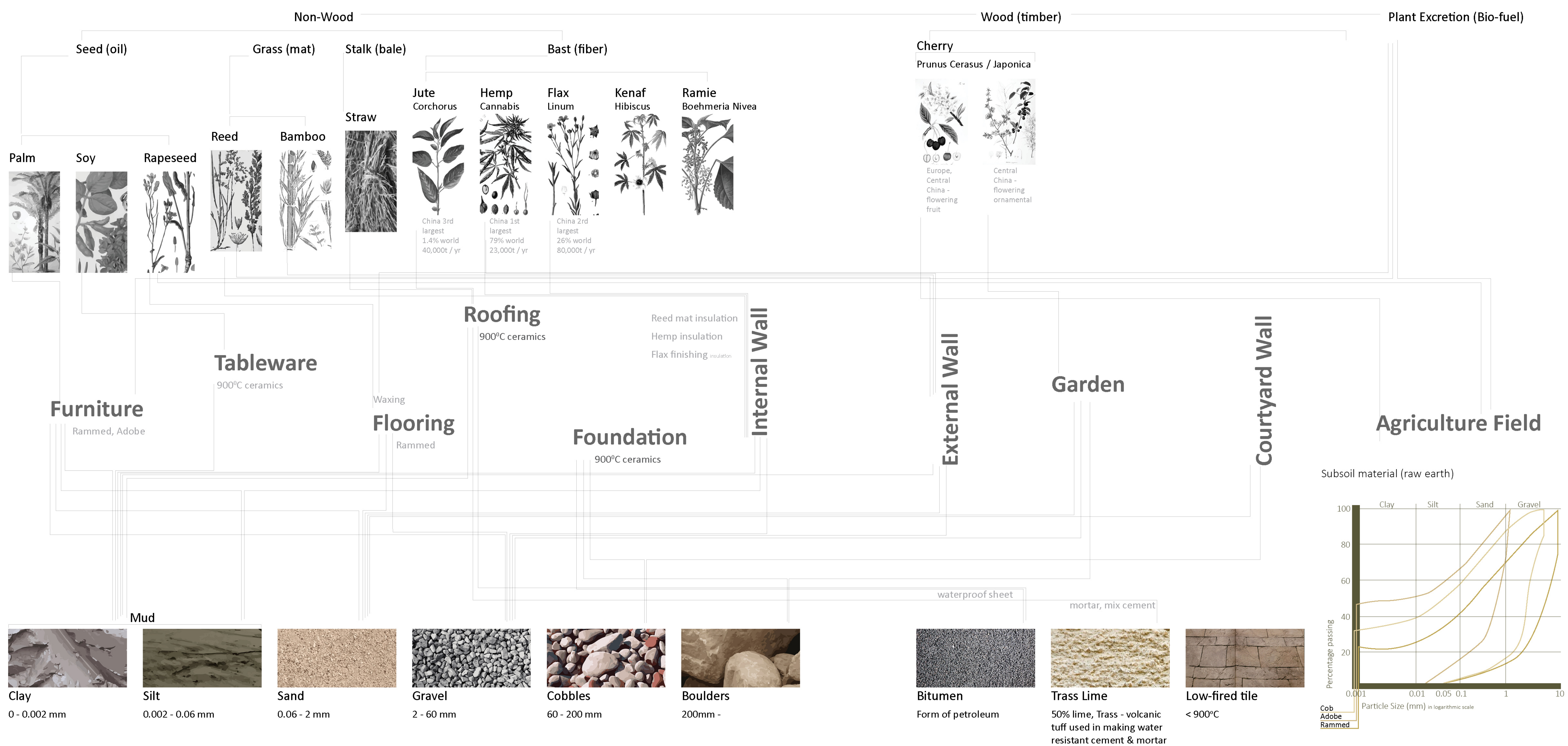
the Rhine



the Loess Plateau of the Yellow River



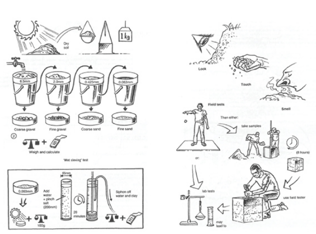
1.1.2. Topsoil and Subsoil Material



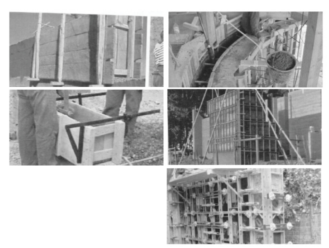
1.1.3. Earthen construction

Rammed Earth

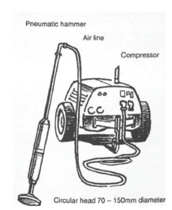
Material Testing
Sand
Water



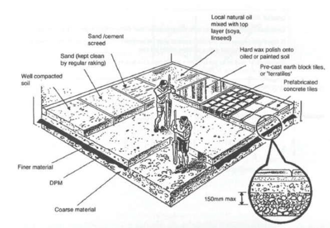
Formwork
Sides
Ends
Corners
Static Formwork:
timber (plywood)
ply-bamboo)
steel



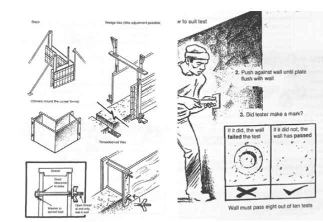
Pneumatic hammer
Circular head 70-150mm
Air line
Compressor



Groundworks



Superstructure



Stability
Use of natural fiber
Trass lime as mortar
Slenderness Wall
Bonding Joint

Not Recommended
Cement
Reinforced Concrete

Detail & Finishing

Rauch Haus @ Schlins Austria

C15+ trasslime Foundation
Steel + Earth
Pre-fab earth steps
Pre-fab glass earth vault
reedmat earthblock
trasslime + steel + clay plaster Lintel
curved formwork system

Maintenance
6-12 months once
better same soil source
rendering and replace

Adobe

Material
Clay and Silt
Water
Straw and Grass

Simple Mold
Manual press
Simple geometry

Drying
Surface exposed
Weeks

Laying & mortar
Coated in water
Mortar bed

Ccompressed Earth Block

Material
Clay and Silt
Water

Complex Mold
Mechanical press
Interlocked form

Drying
Surface exposed
28 days

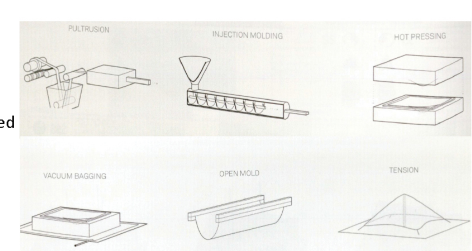
Laying & interlock
NO Mortar
Highly recyclable

Flax Composites

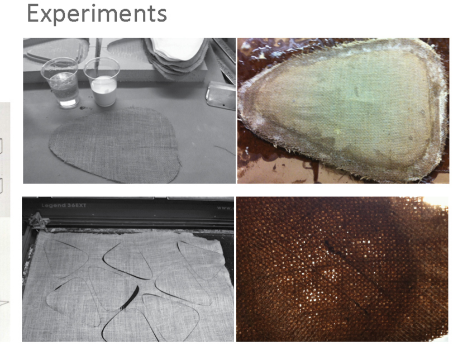
Fiber

Matrix
Epoxy, PP,
1. Natural polymers
2. Bio-based polymers (PLA, PHA,PHB...)
3. "Synthetic" petroleum based polymers
(PBS, PCL, PP, PE, UP...)

Processing

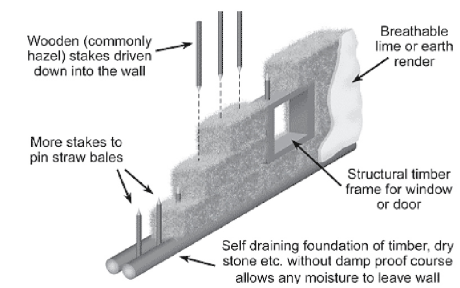


Experiments



Straw Bale

In Situ



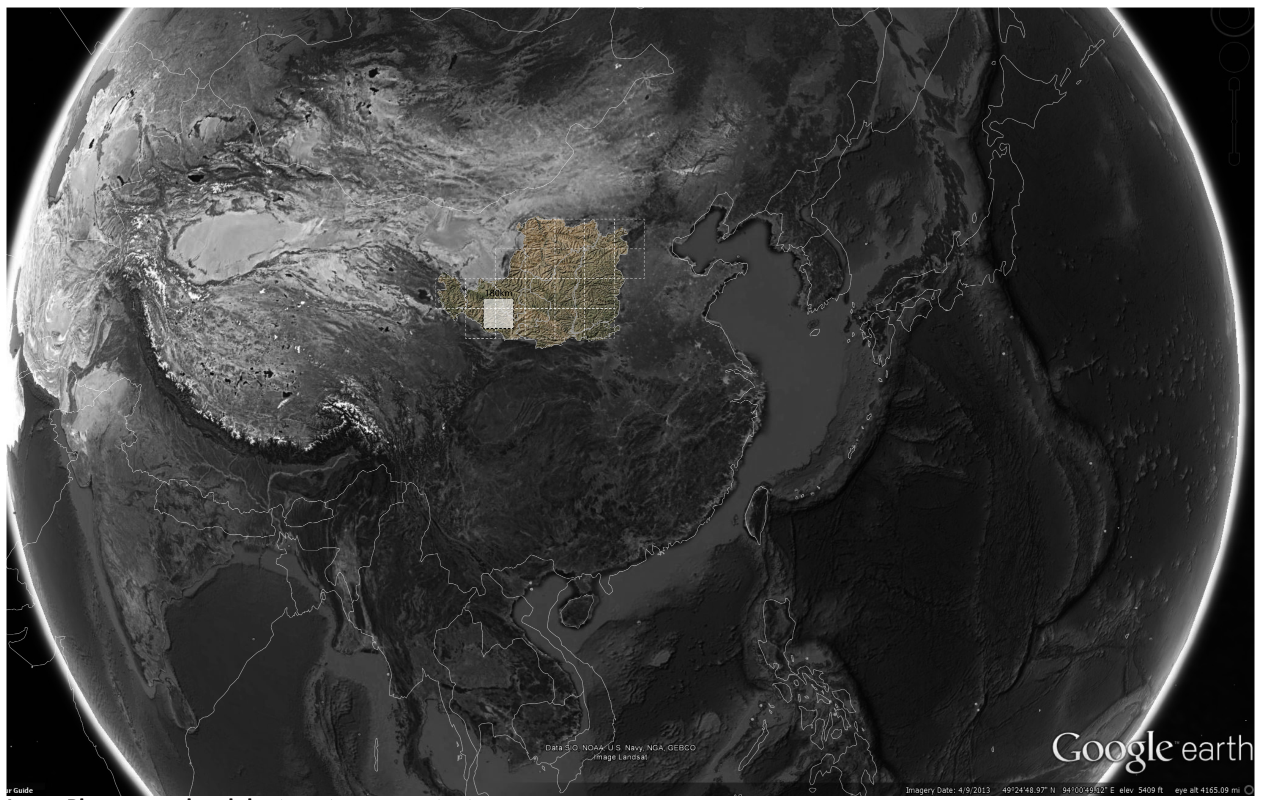
Prefabrication

640,000 km^2
= 800 km x 800 km

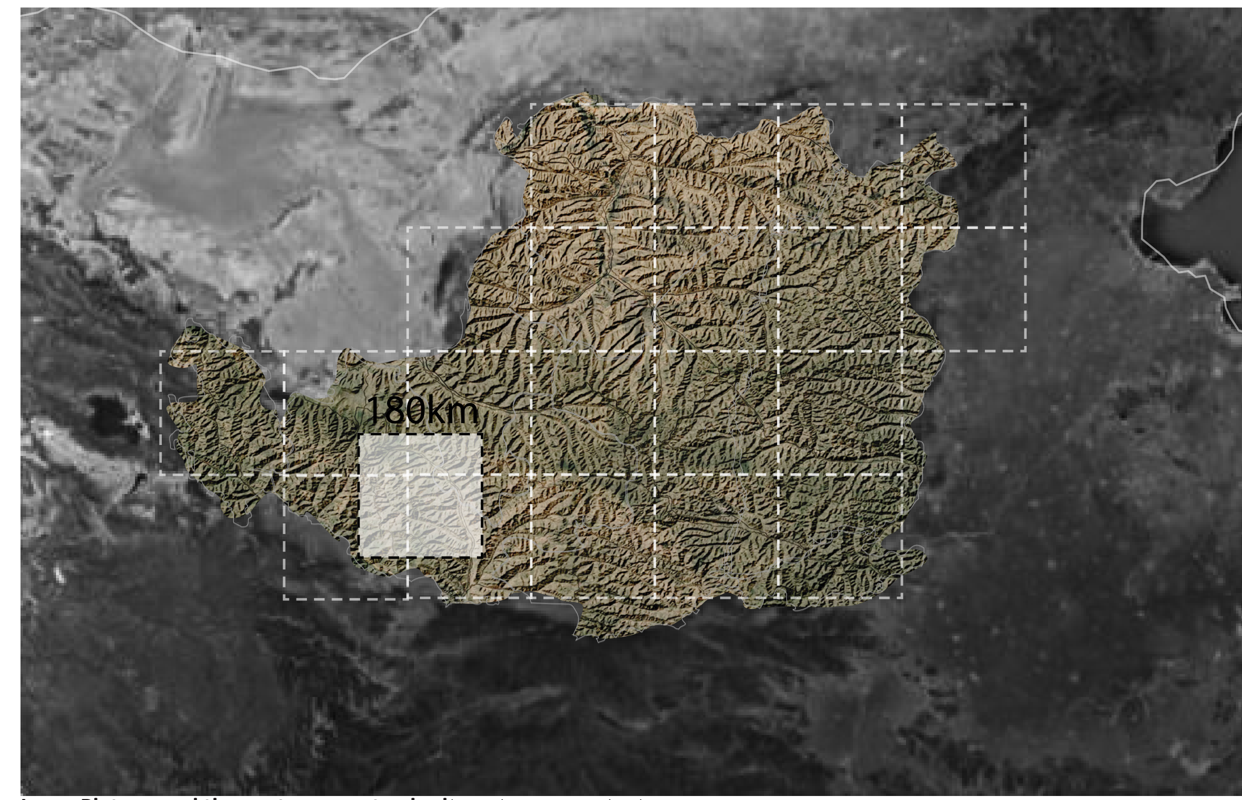
Loess Plateau is in the hearten area of Yellow River, with its civilization tracing back to 5000 years ago. The average 150 meters loess layer made the region the birthplace of rammed-earth and adobe construction in China.

The west part of the Loess Plateau is at the upstream of the Yellow River, which is the starting area of soil erosion. Soil loss area is tripe to the agricultural area, affected by both the wind and the water. Around 150,000 households live in erosive hill and valley areas whose income far below the average. Annual precipitation is 400mm and rainfall concentrates in summer. Construction season is from July to October. Comparing raw earth to fried brick or concrete, it doubles the affordability by building with raw earth.

1.2.1. Loess Plateau Map

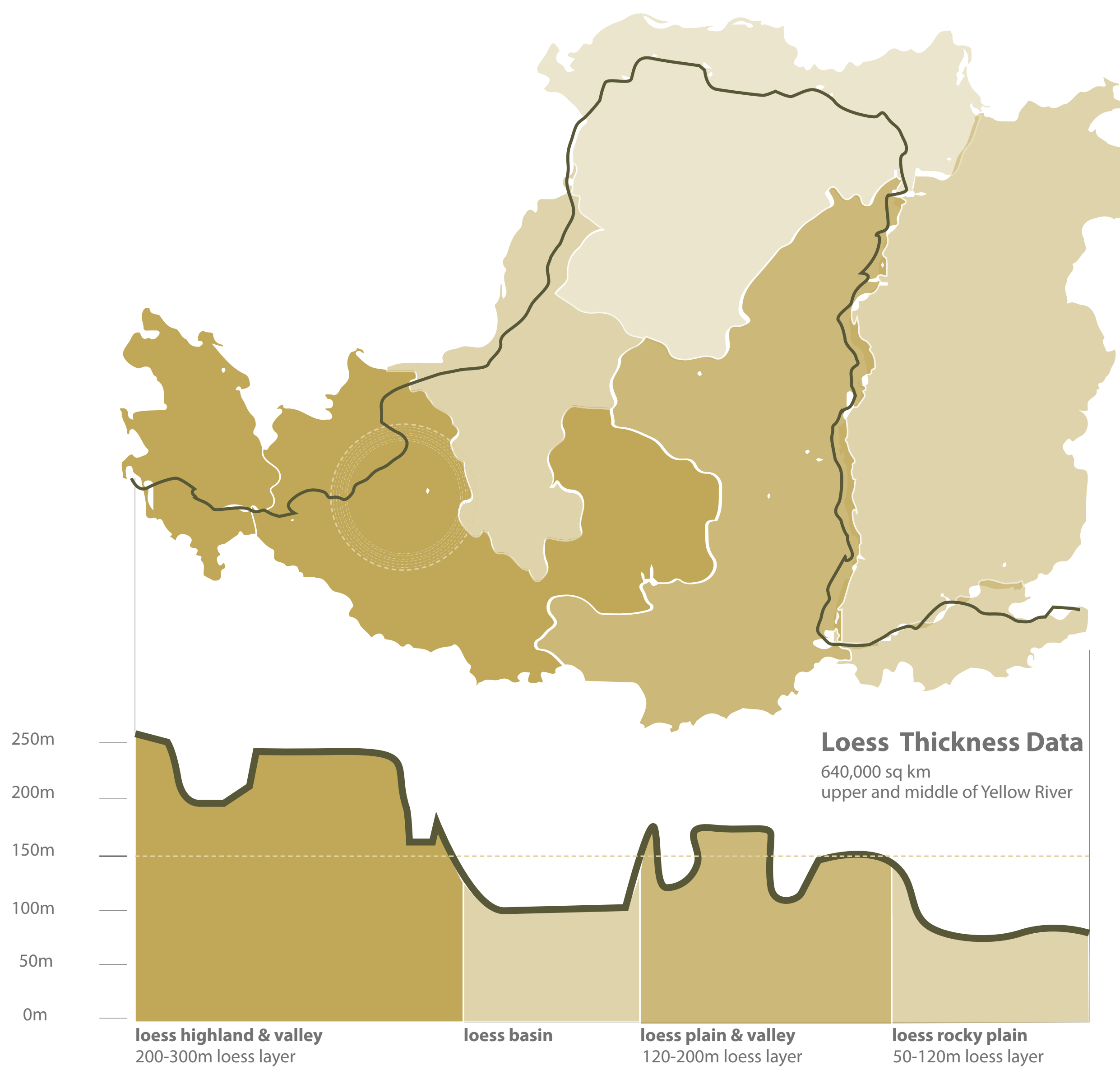


Loess Plateau on the globe (Google map, GIS data)

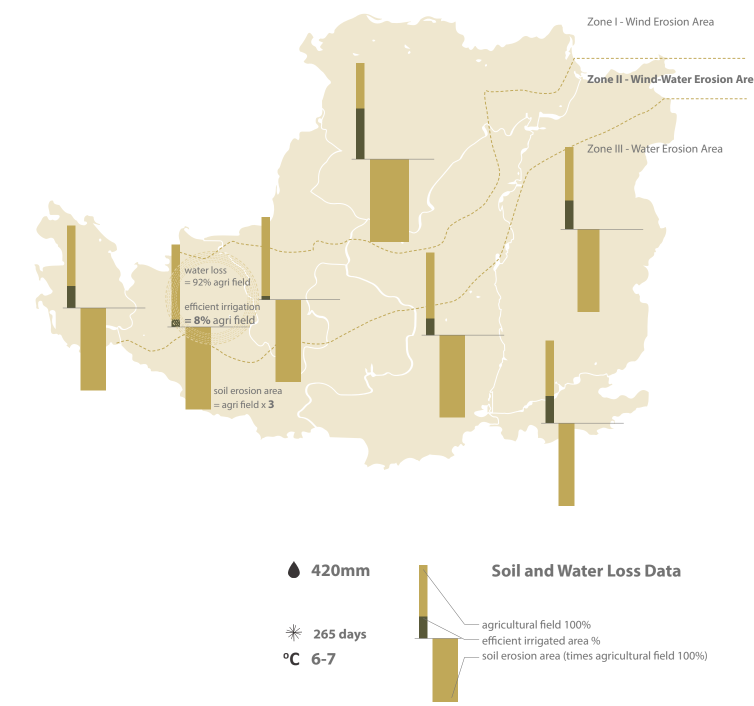


Loess Plateau and the upstream watershed(Google map, GIS data)

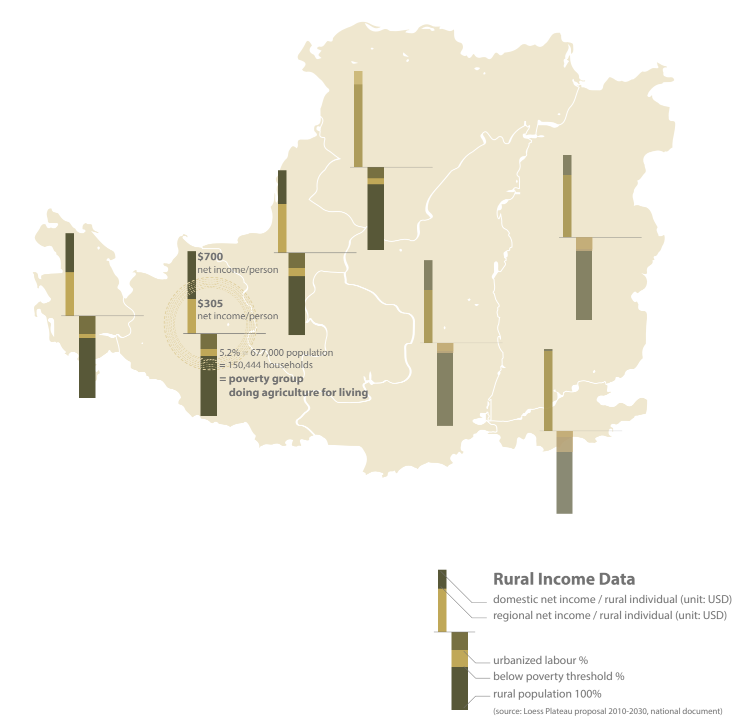
1.2.2. Loess Plateau Data



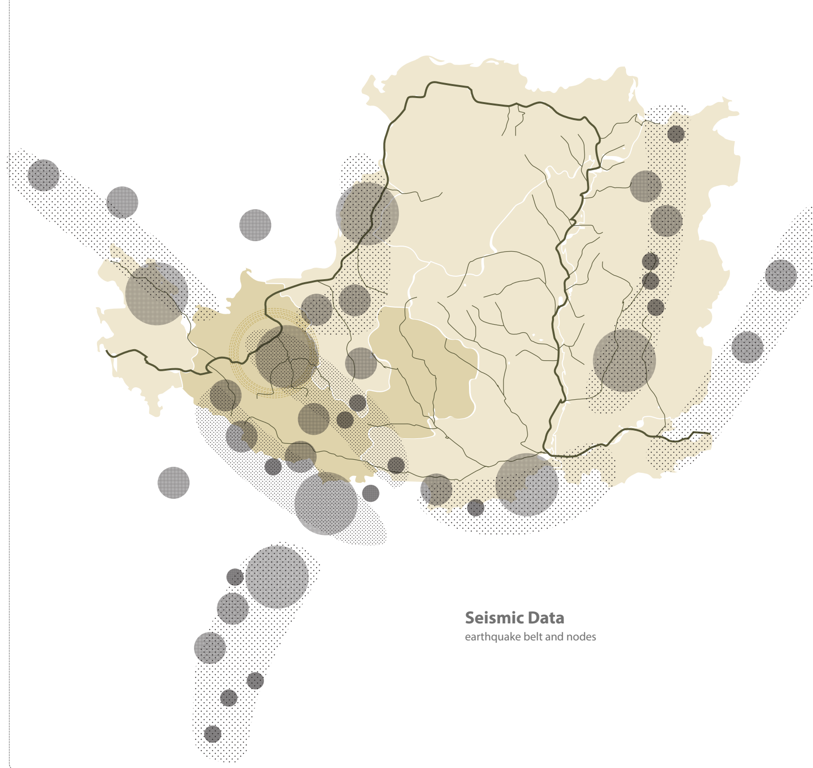
Soil erosion occurs crisscrossed with winter wind erosion and summer water erosion.



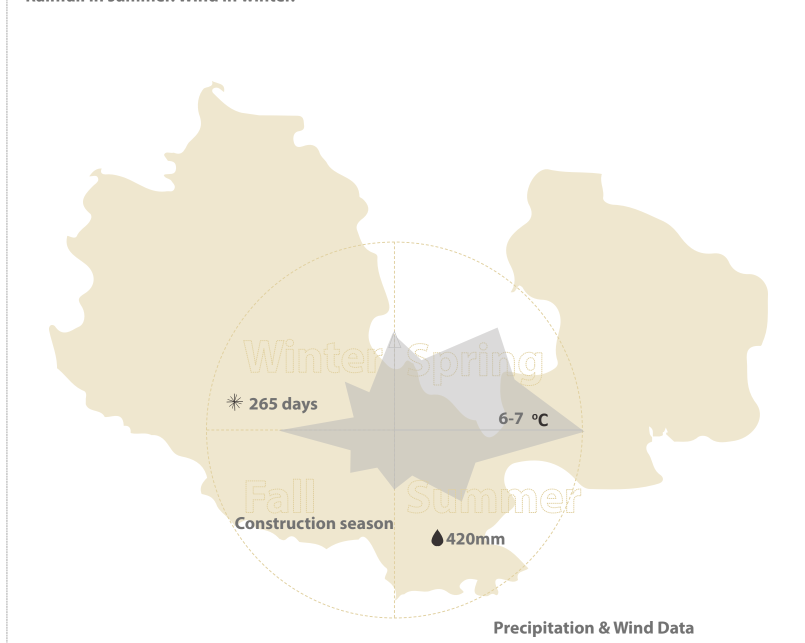
Design for poverty households who make living with agriculture.



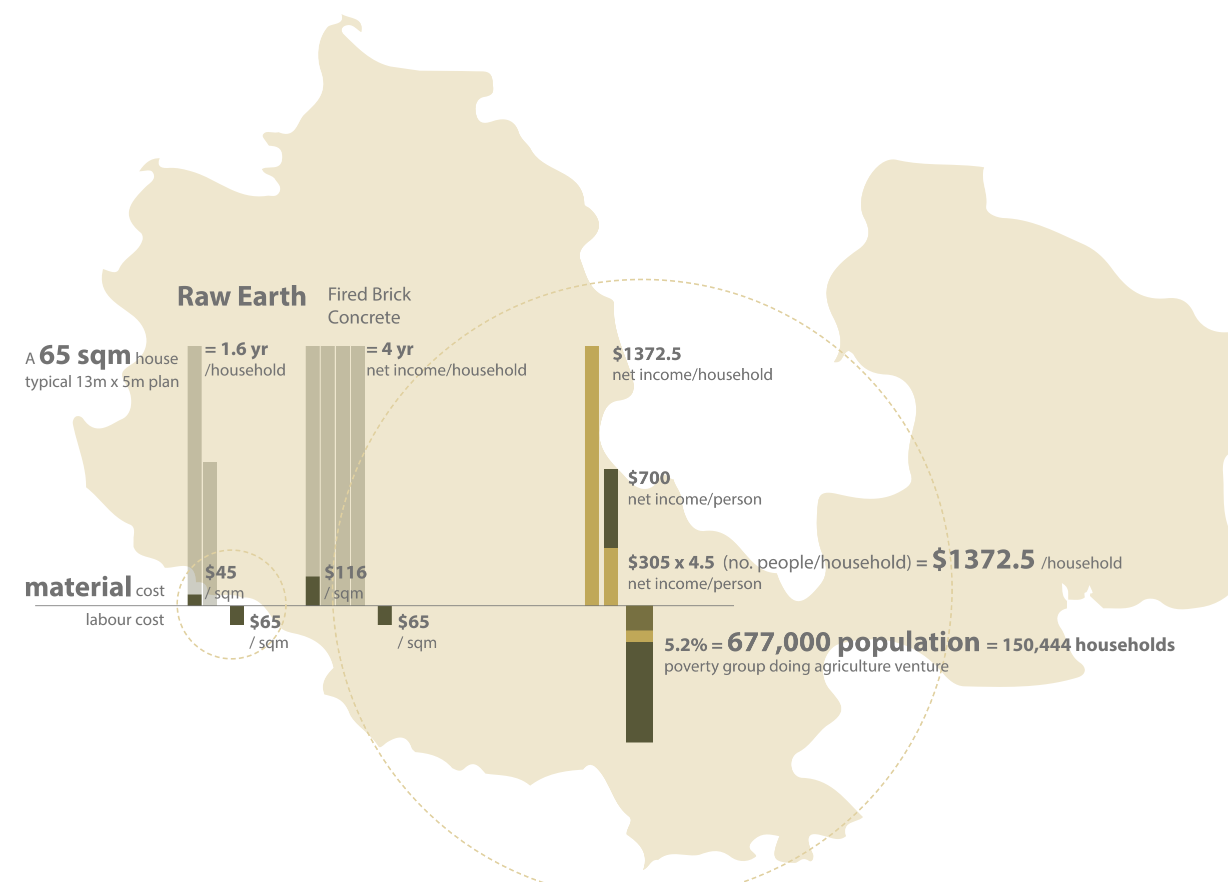
Intersection of South-north and East-west earthquake belt.



Rainfall in summer. Wind in winter.



Raw earth as major building material makes house renewal more affordable.



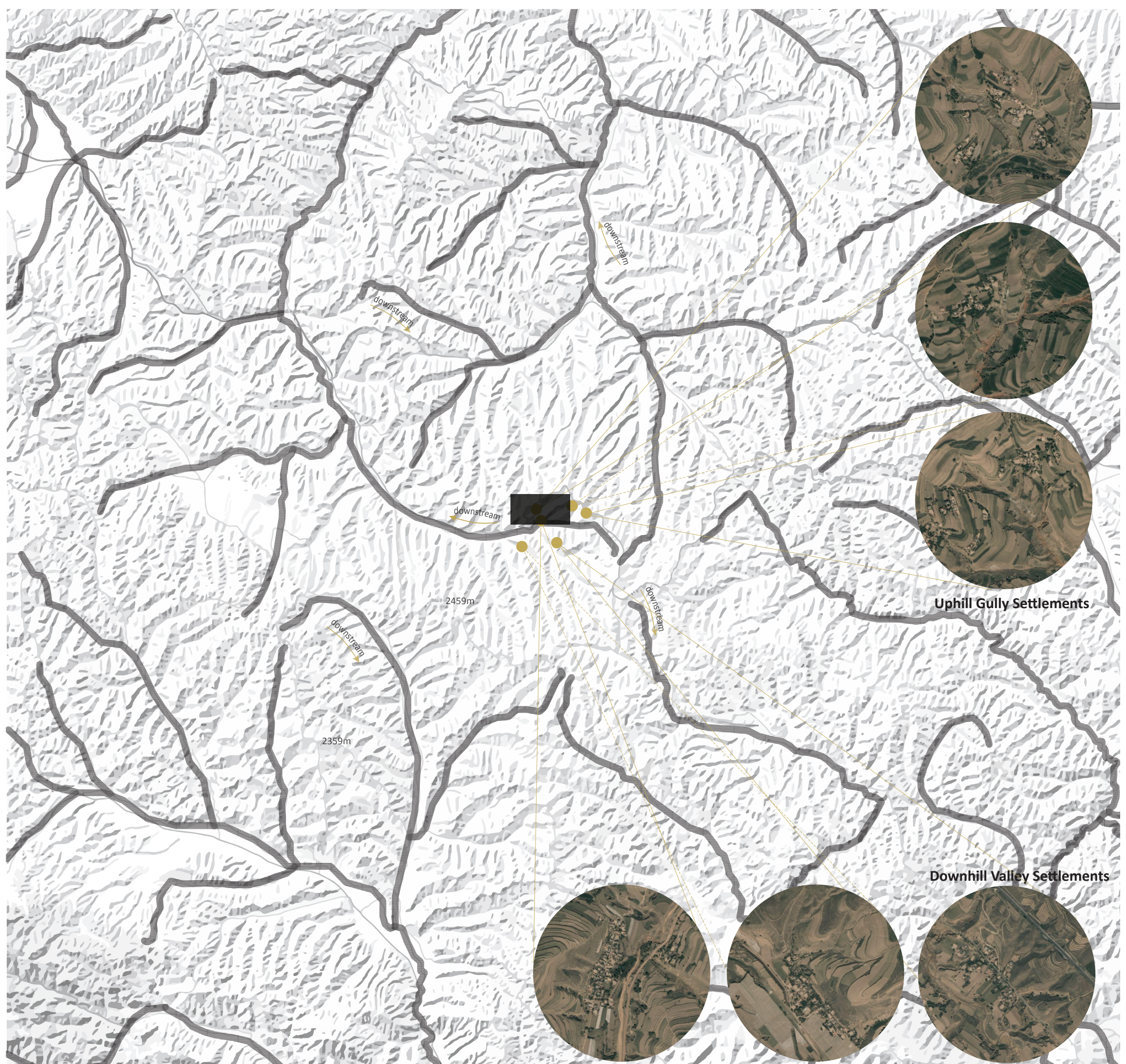
House Affordability Data

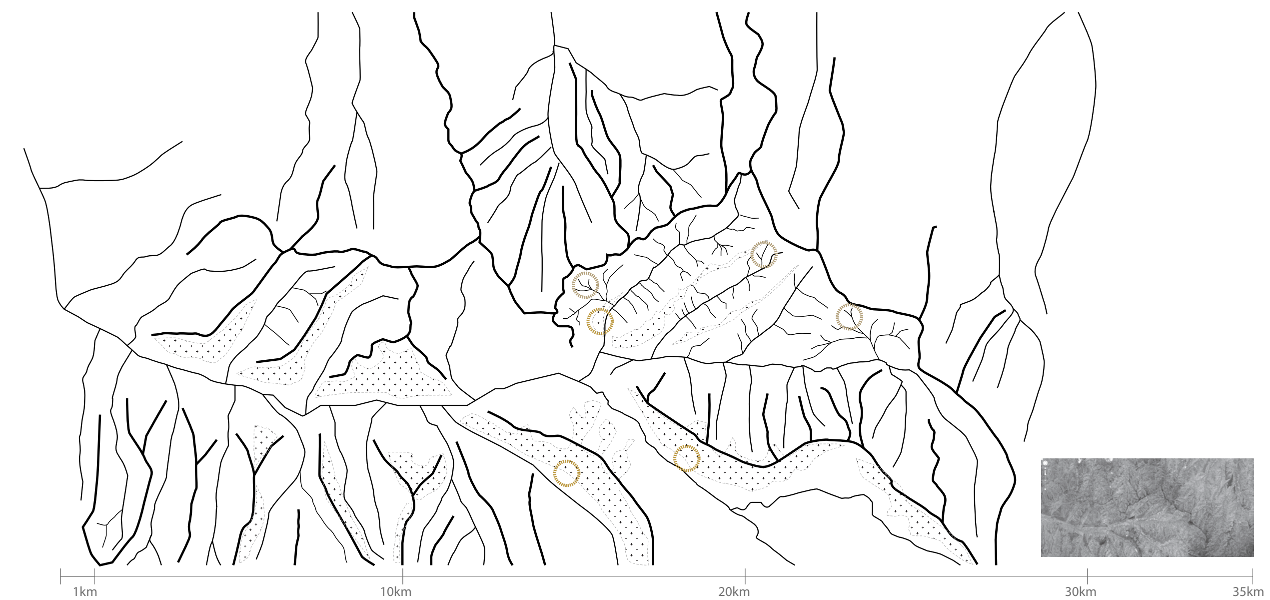
Take a typical 65 sqm house as example.
Compare material cost raw earth with conventional mate

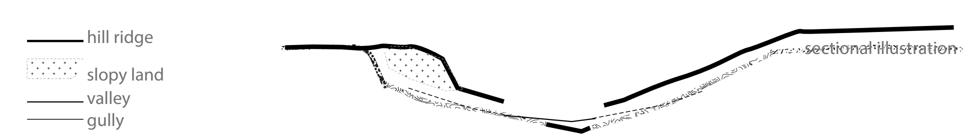
32,400 km^2
= 180 km x 180 km

The upstream of the Loess Plateau is the starting area of soil erosion. Gradient strips present the pattern of hill and valley sub-watershed system. Agricultural settlements situate at gully branches or valley slopes.

1.3.1. Upstream Watershed Map



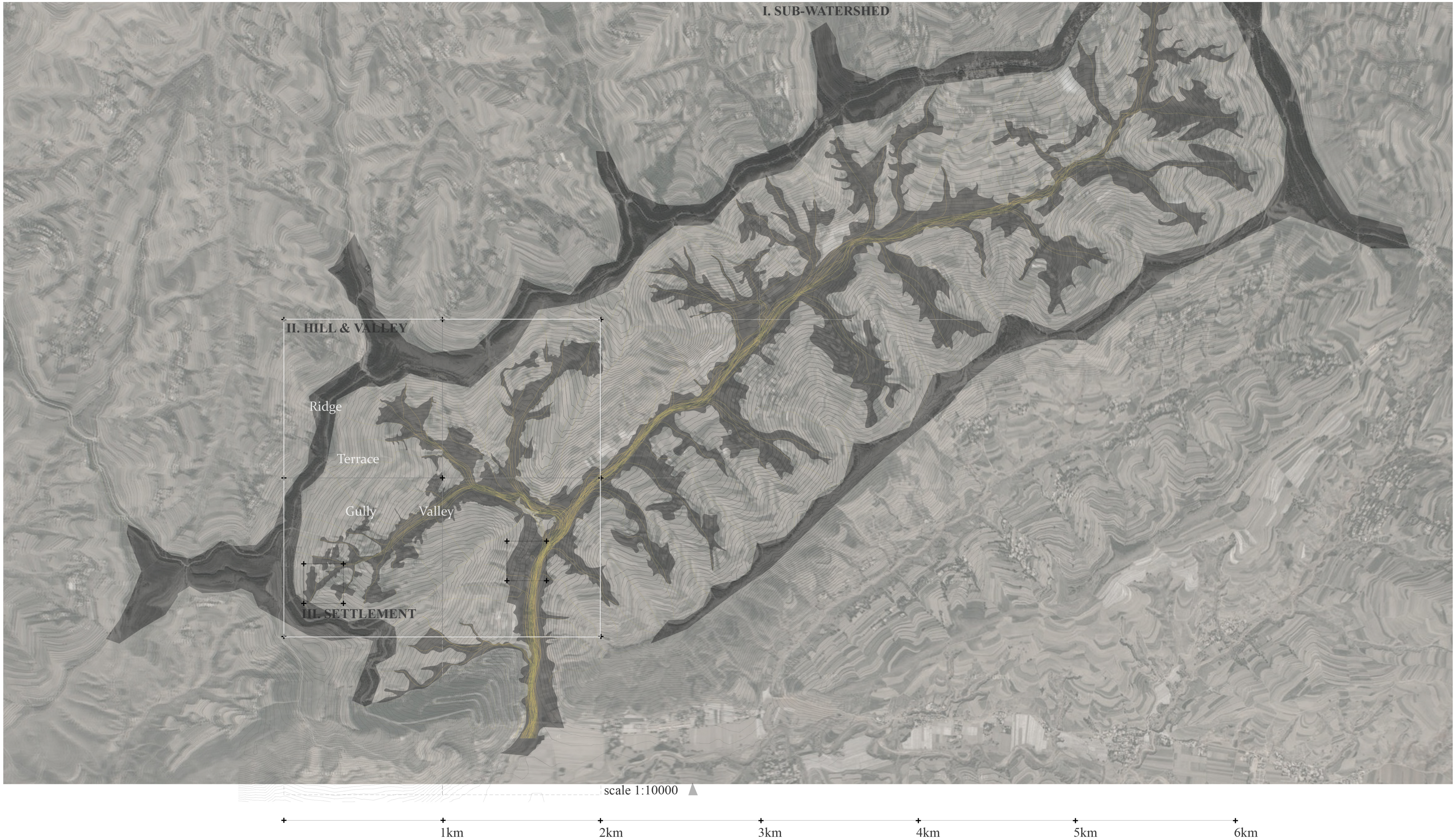




36 km^2
= 6 km x 6 km

A typical sub-watershed area composes of a ridge, a branched-out gully / valley system, and terraced farmlands in between. Exposed soil cuts and slopes in a gully area are the main source of soil loss.

1.4.1. Sub-watershed Map



1.4.2. Sub-watershed Landform

Sub-watershed landform, cuts, slopes and gullies. Photo by Bin Li. March 10th, 2013. Xiaowan village group, Huining, western loess plateau.

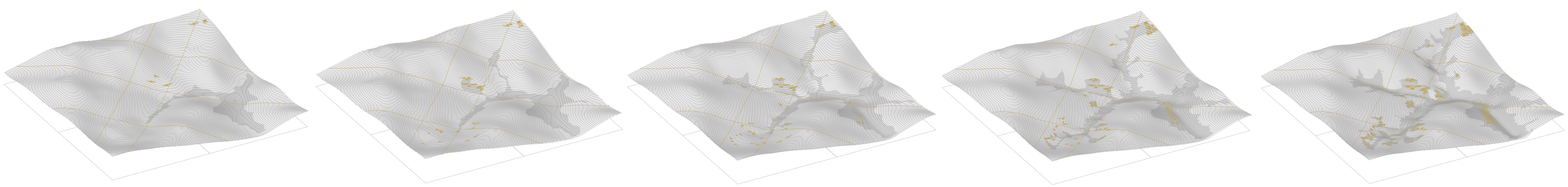
$4\ km^2$
$= 2\ km \times 2\ km$

A typical hill and valley area is part of sub-watershed system. It contains all the landscape features of the sub-watershed.

In the hill and valley scale, the evolution of eroding landform and settlement can be analyzed. The growth of gully branches was correlated with the growth of the uphill settlements. The downhill settlements were developed later.

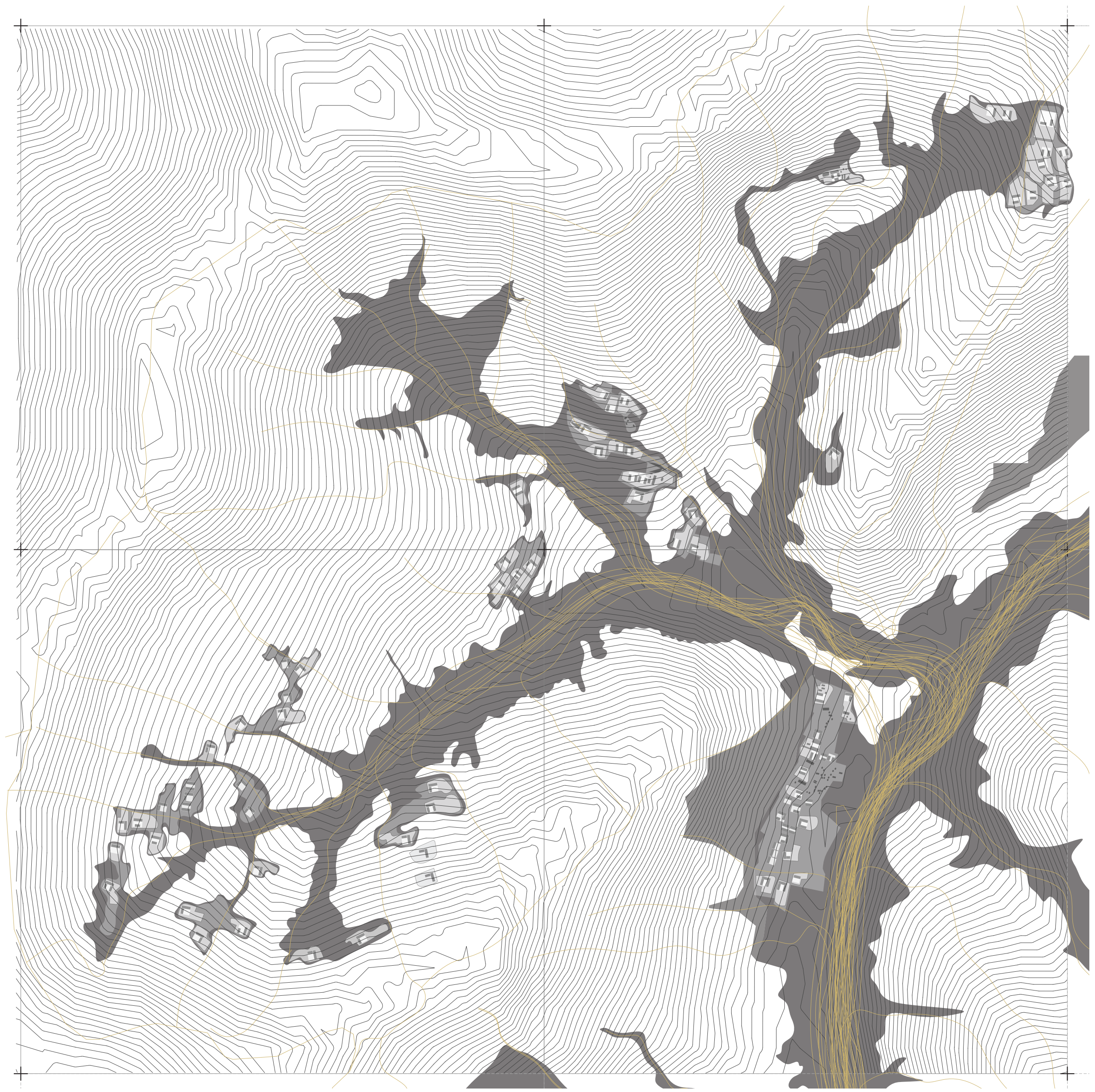
Erosion assessment indicates that gully erosion, which happens in gully and valley areas, creates soil loss of 8400 m3 per year. This amount of soil can be used to build 60 dwellings of the existing type.

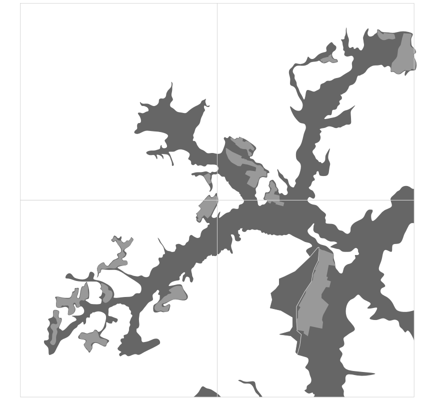
1.5.1. Evolution of Eroding Landform and Settlement



Evolution Model (white and black clay on 3d-printed topography)

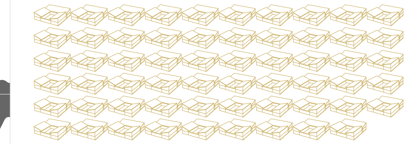
1.5.2. Erosion Assessment



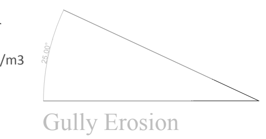


on valleys

8400 m3/ yr = 60 dwellings

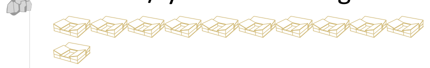


0.9 km2
x 12000 ton/km2 / yr
= 10800 ton / yr
loess density: 1.3 ton/m3

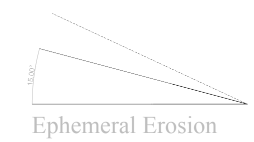


on settlements

1500 m3/ yr = 11 dwellings

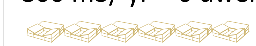


0.13 km2
x 7300 ton/km2/yr
= 950 ton/ 5 months water erosion
loess density: 1.3 ton/m3

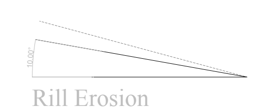


on households

800 m3/ yr = 6 dwellings



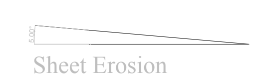
0.067 km2
x 6800 ton/km2/yr
= 456 ton/ 5 months water erosion
loess density: 1.3 ton/m3



on dwellings

100 m3/yr = 1 dwelling

0.027 km2
x 2000 ton/km2/yr
= 54 ton/ 5 months water erosion
loess density: 1.3 ton/m3



1.6. Settlement

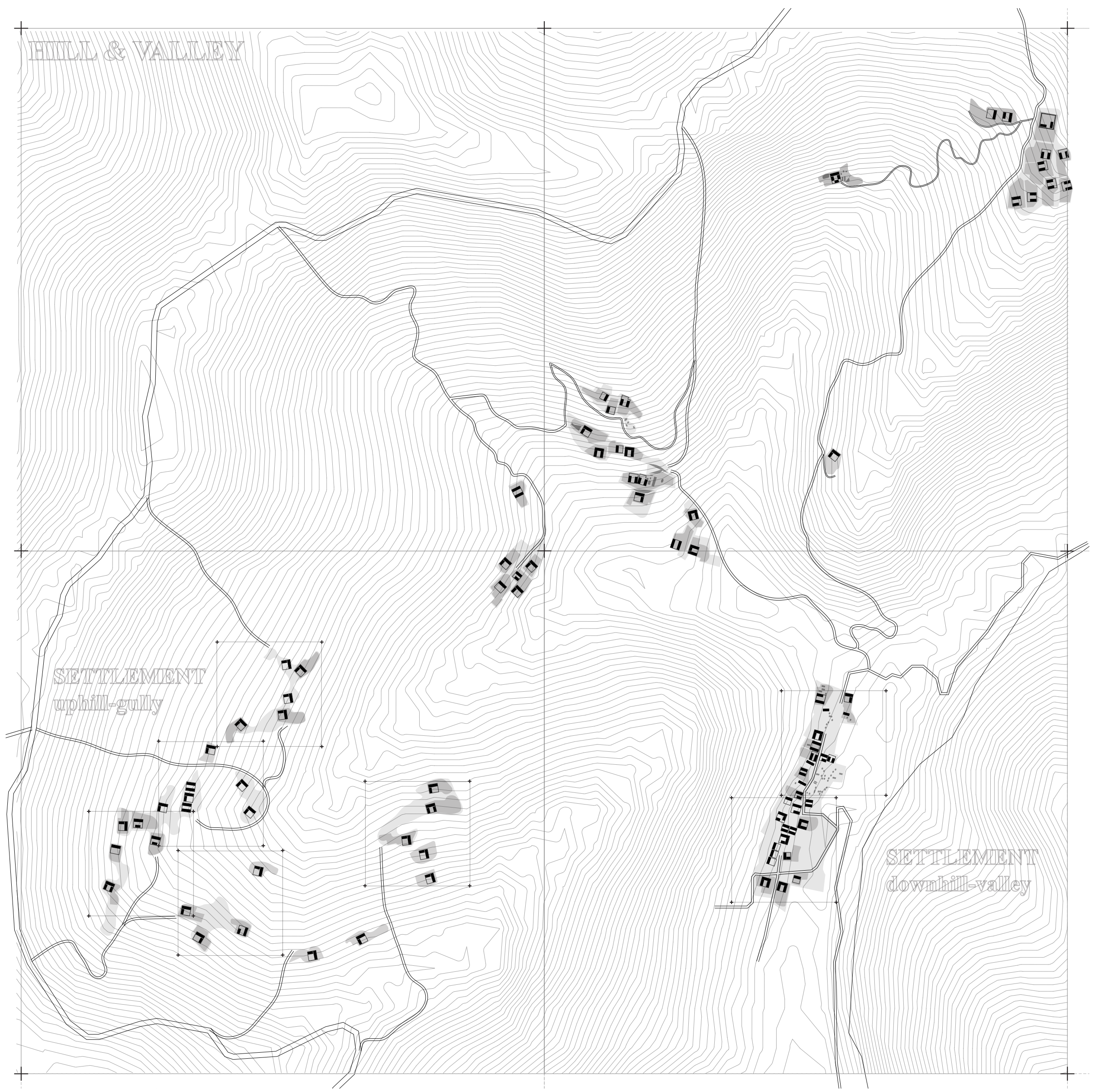
$40{,}000\ m^2$
$= 200\ m \times 200\ m$

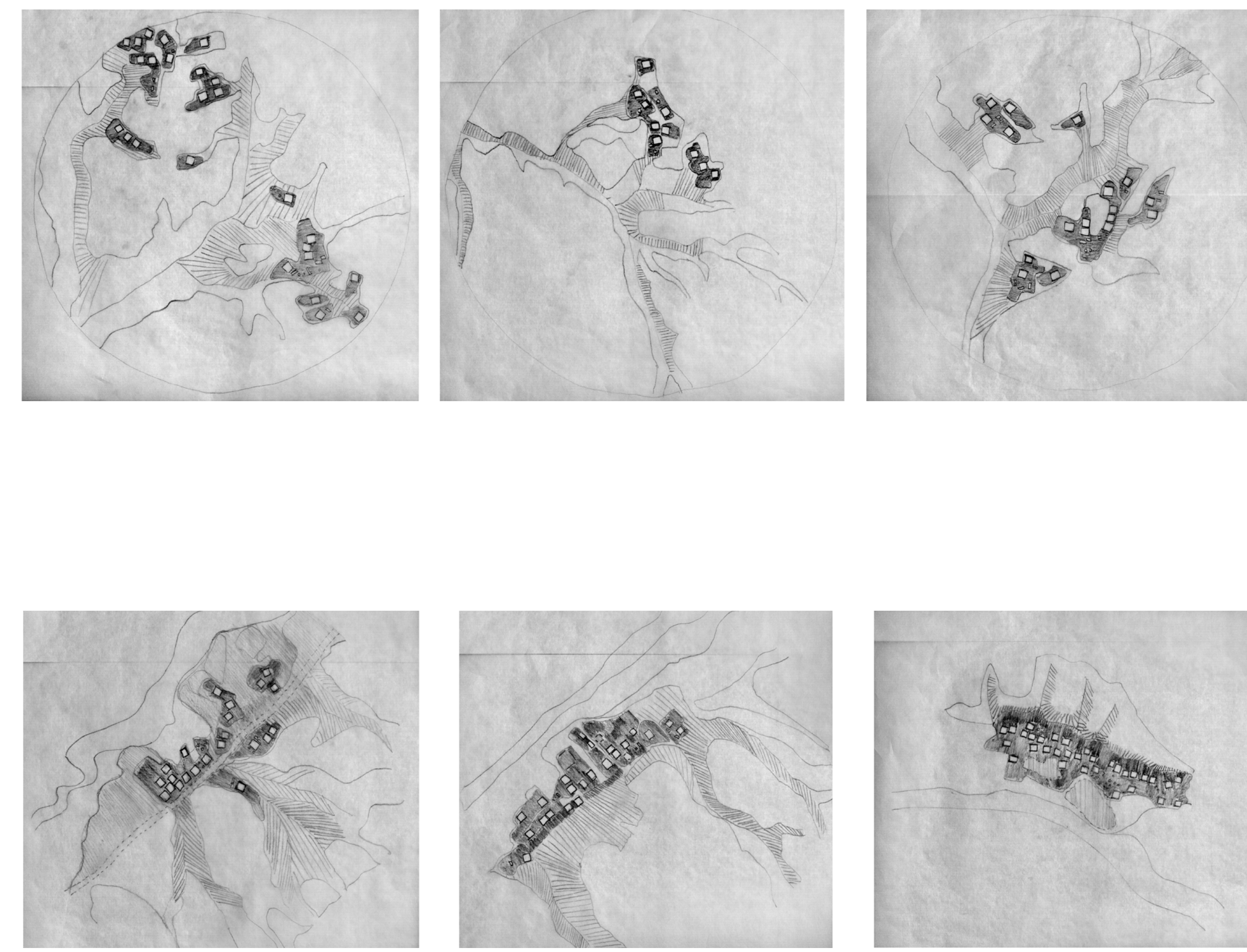
Two types of settlements can be found in a typical hill and valley area: the uphill-gully type and the downhill-valley type.

The uphill-gully settlements locate at the head of gully branches, an average of 5 households per 40,000m2 land. The accessibility is from the ridge down.

The downhill-valley settlements locate at the edge of the valley and adjacent to a hill slope, an average of 15 households per 40,000m2 land. The accessibility is from the valley up.

1.6.1. Settlement Map





Settlement sketch (Pencil, charcoal on paper)

1.6.2. Uphill-gully & Downhill-valley Settlement

Uphill-gullly settlement. Photo by Bin Li. March 10th, 2013. Xiaowan village group, Huining, western loess plateau.

Downhill-valley settlement. Photo by Bin Li. March 11th, 2013. Yanshan village group, Huining, western loess plateau

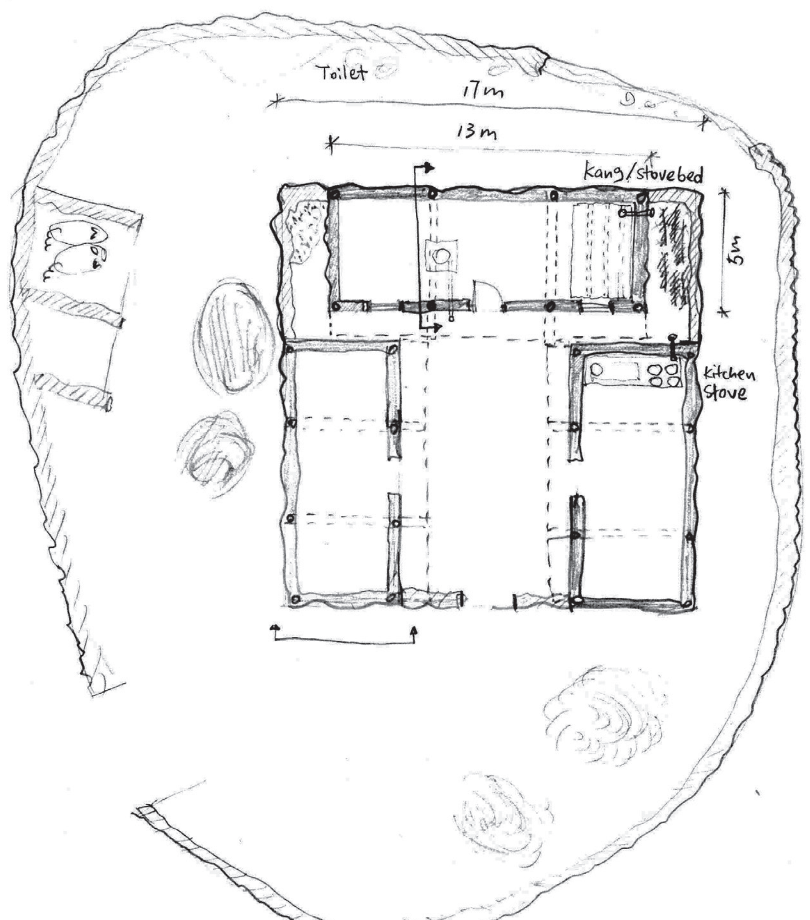
1.7. Dwelling

400 m^2
= 20 m x 20 m

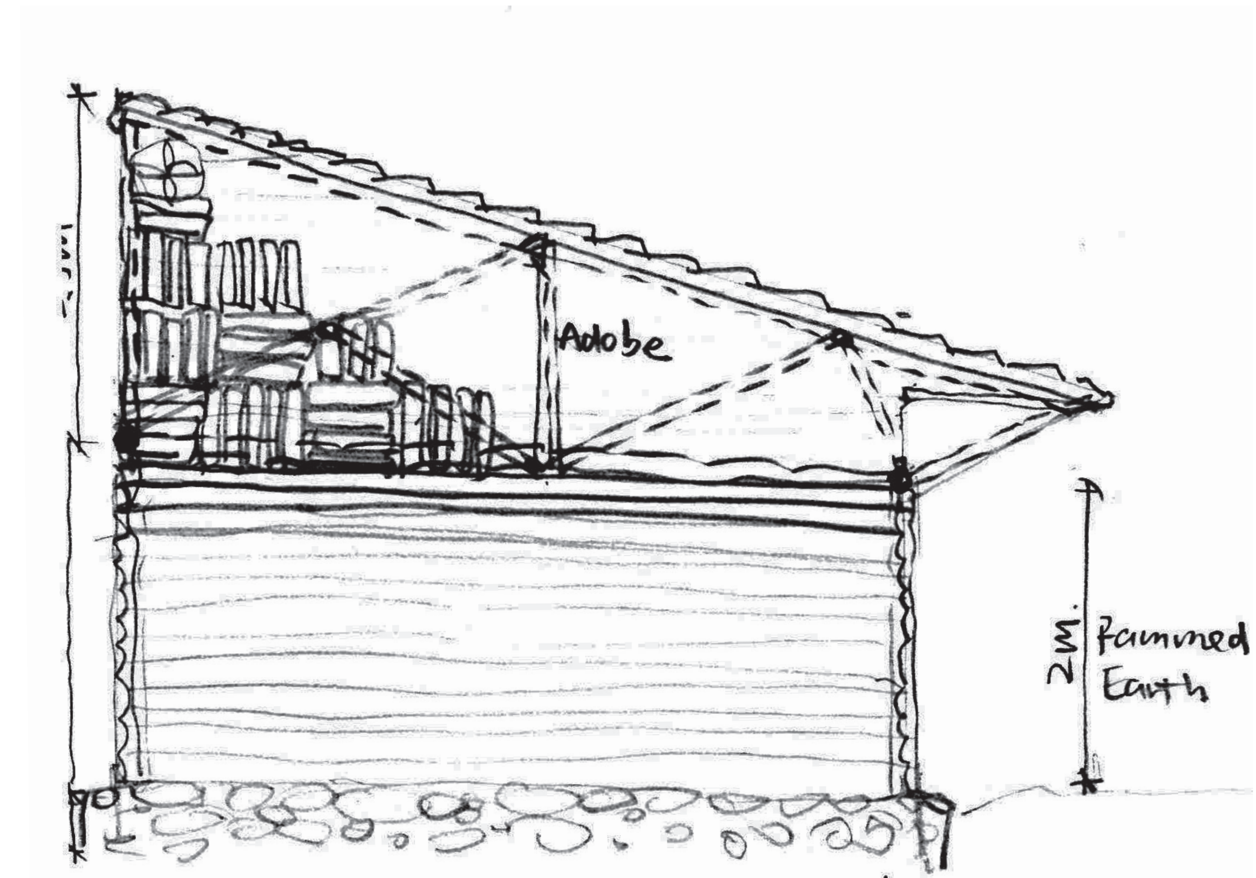
A traditional earthen dwelling occupies roughly 300 m2 living quarter with an inner courtyard and an earthen wall enclosing an outer courtyard. Foundation was constructed with cobbles. Wall was constructed with rammed earth up to the roofing level. Adobe wall was constructed further up. Two pieces of timber truss supported the roof.

The landform was subtracted while the built form was added. Households digged into the nearby exposed loess section and created exposed earthen wall. This process doubled the exposed soil loss area.

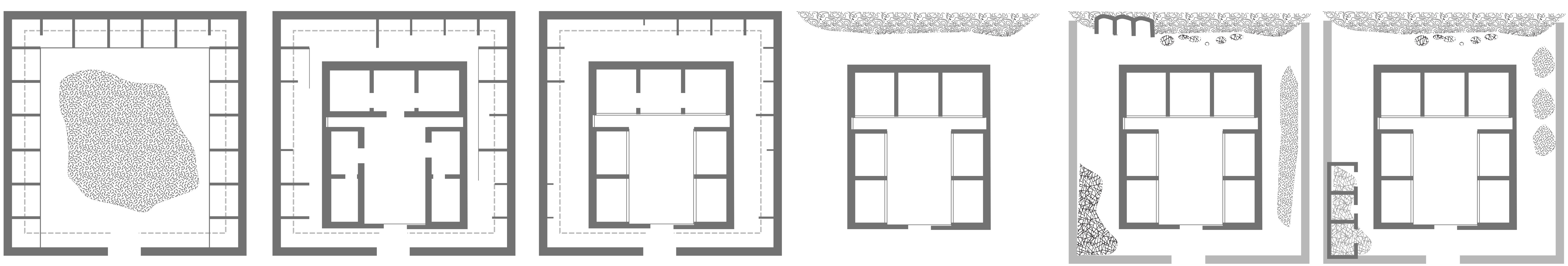
1.7.1. A Traditional Earthen Dwelling



Dwelling Plan (Pencil, charcoal on paper)



Dwelling Section (Pencil, charcoal on paper)

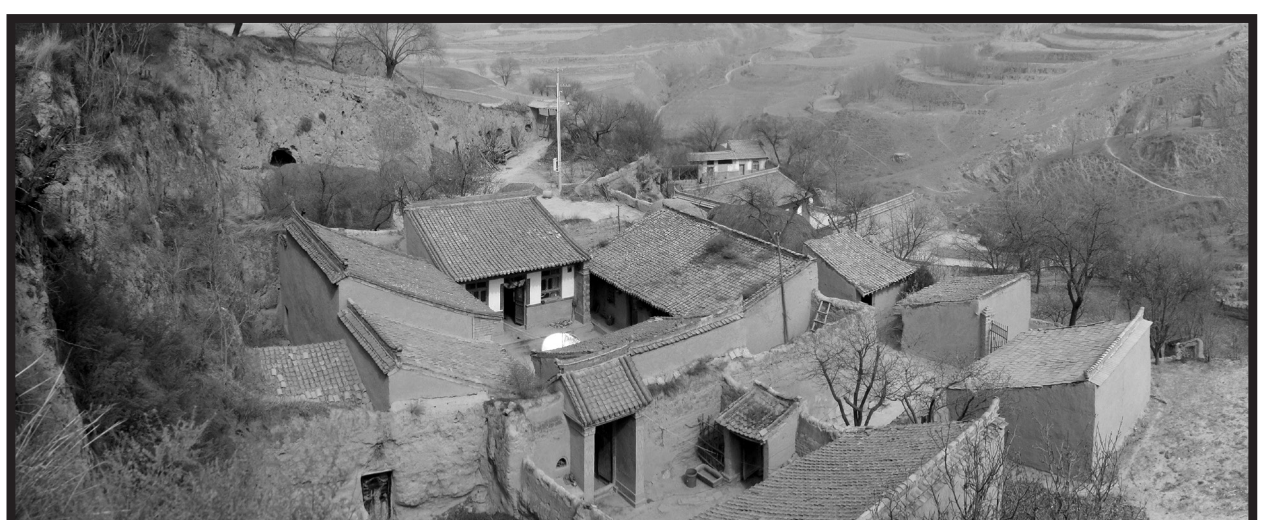


1900s 1920s 1940s 1960s 1980s 2000s

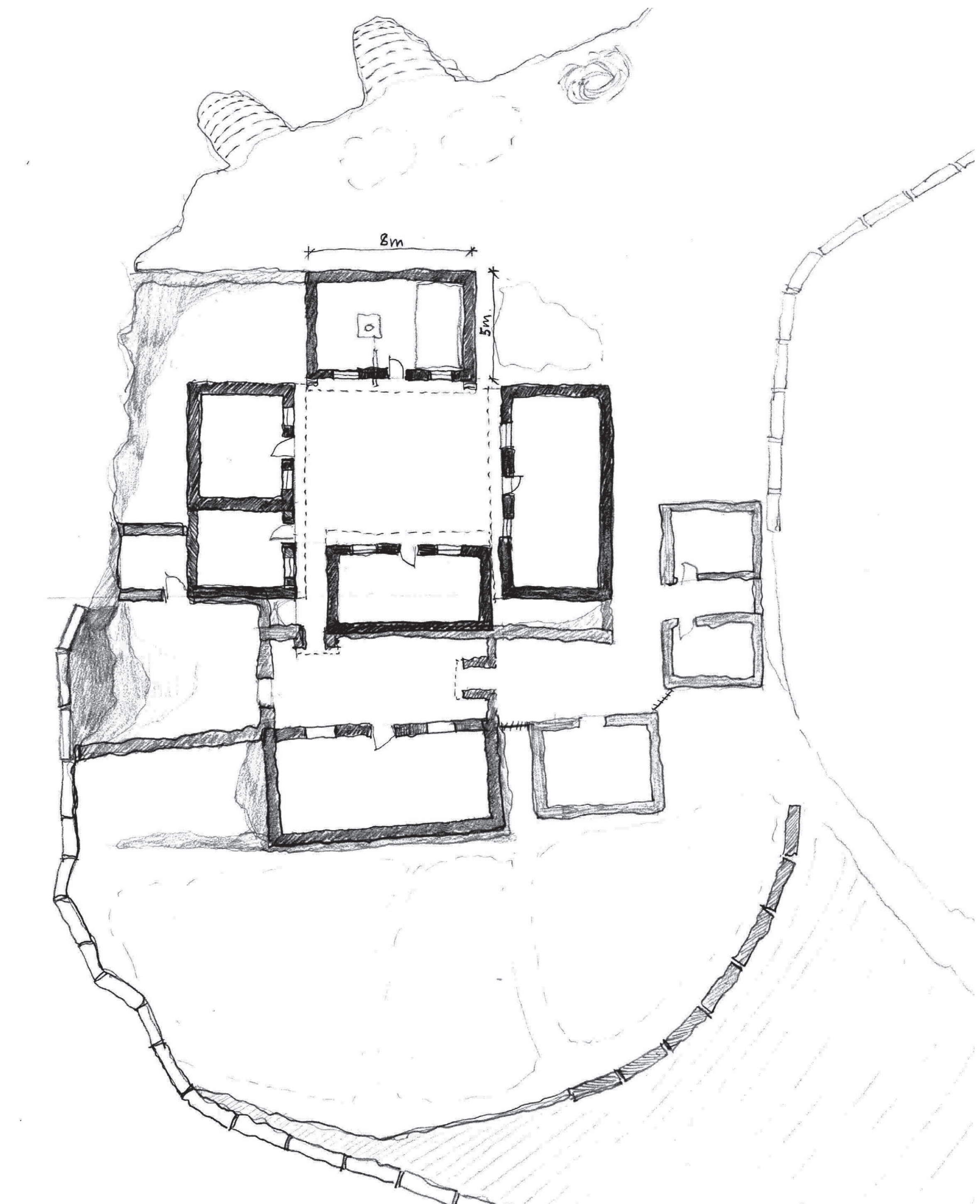
1.7.2. Built Form and Landform

Photo by Bin Li. March 10th, 2013. Xiaowan village group, Huining, West Loess Plateau.

A man was digging soil from explored loess section to build his new house nearby.



Current built from & landform Photo by Bin Li. March 9th, 2013. Yanshan village group, Huining, West Loess Plateau.



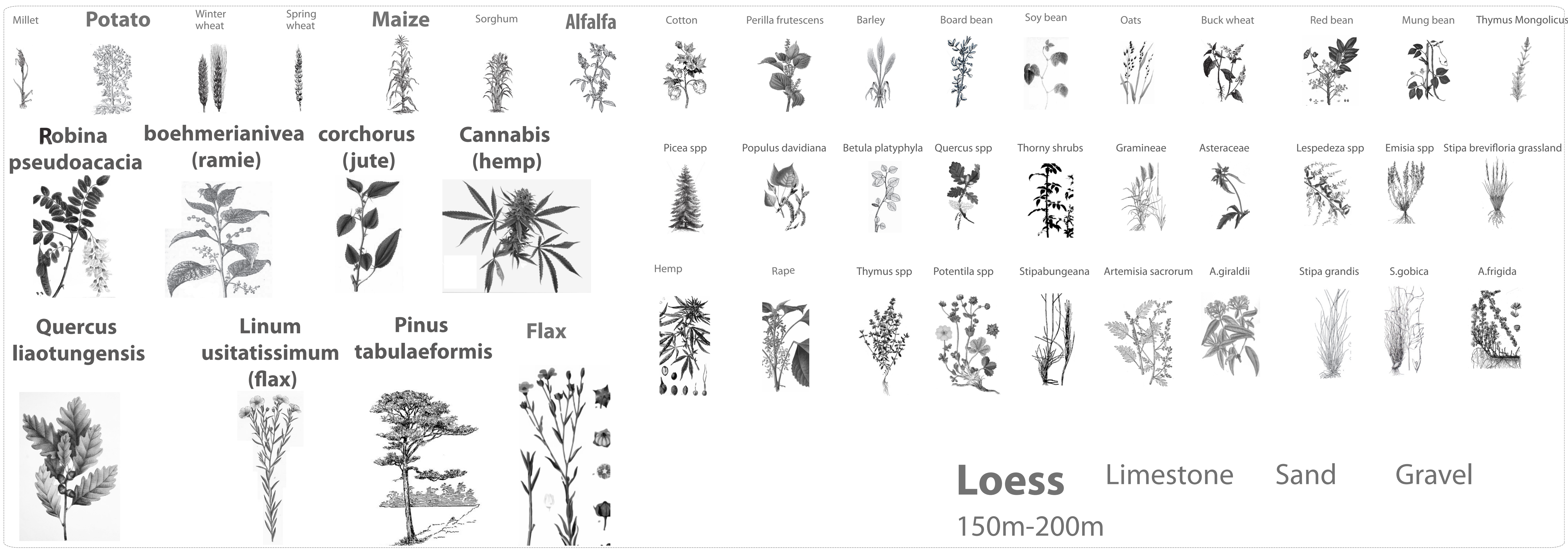
Dwelling and Landform (Pencil, charcoal on paper)

4 km^2 = 2 km x 2 km

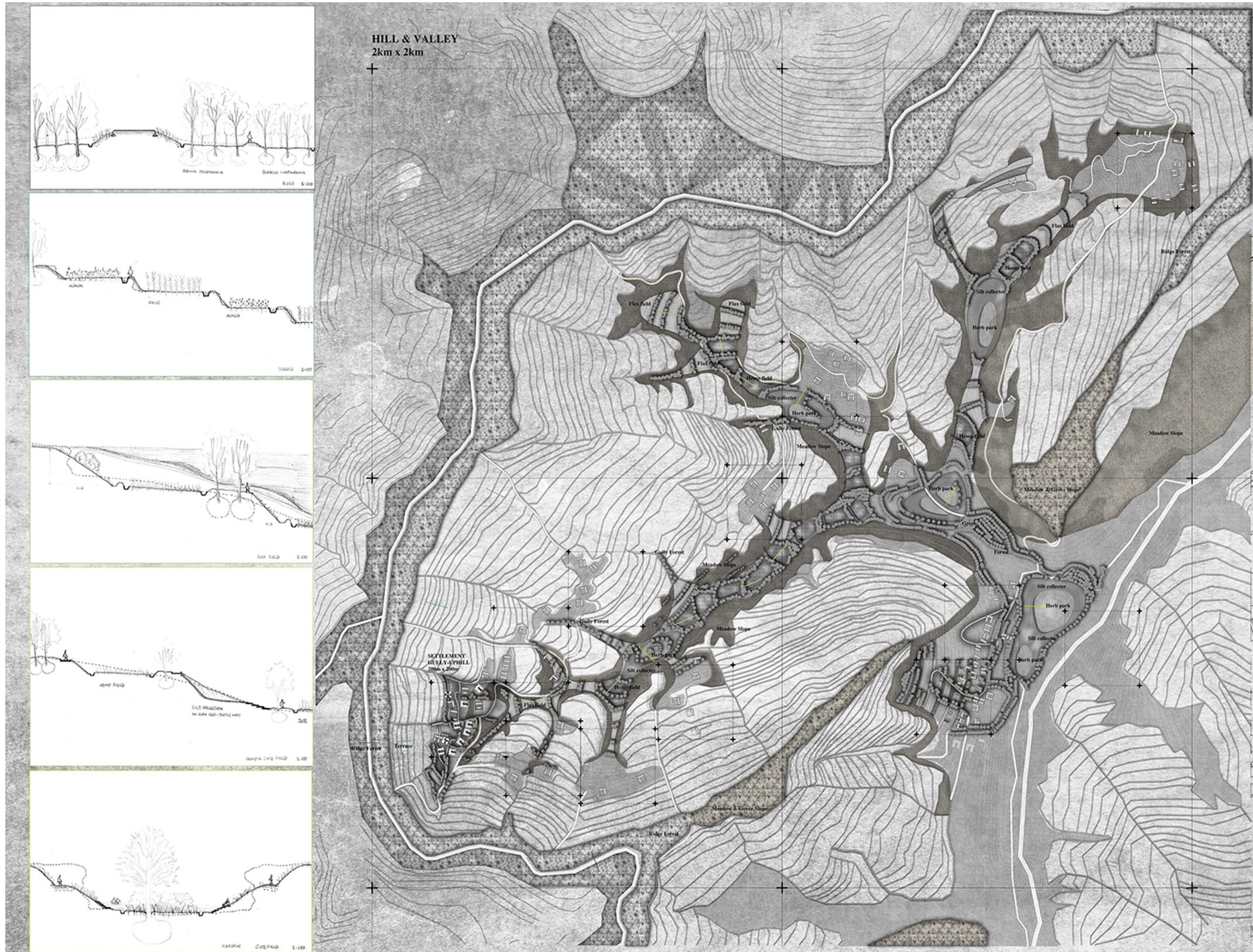
The vegetated landform include using local plant species, creating both belt and mix zones, locating herb fields, and planting from the ridge to the valley. It aims to slow down soil erosion process at the scale of hill and valley. Design actions involve grading steep cuts into stepped slopes, planting tree species on the ridge and the steep gullies, shaping gully edges into meadow slopes, and creating herb fields in the gully/valley basins.

The main local species for reforestation are Robina Pseudoacacia and Quercus Liaotungensis. Herb species - Linum Usitatssimum (flax), Cannabis (hemp), and Corchorus (jute) – are for stabilizing the sloppy and gully areas.

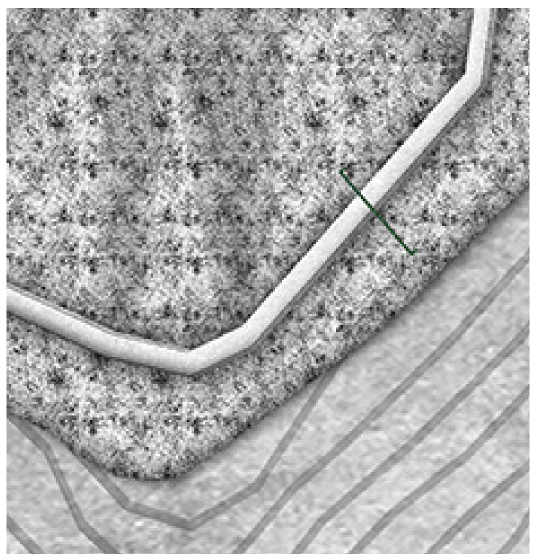
2.1.1. Local Plant Index

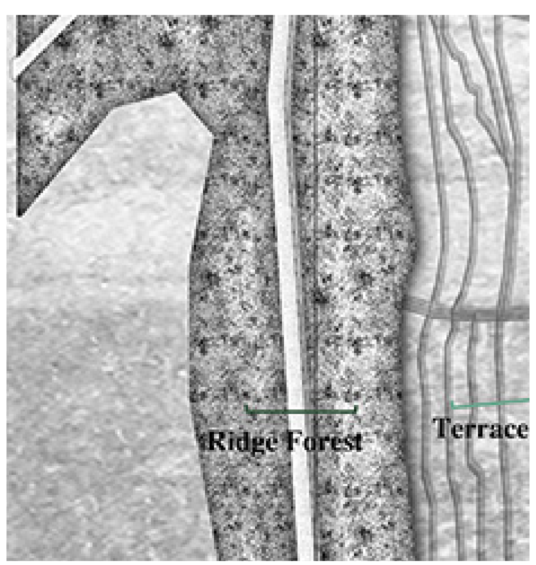


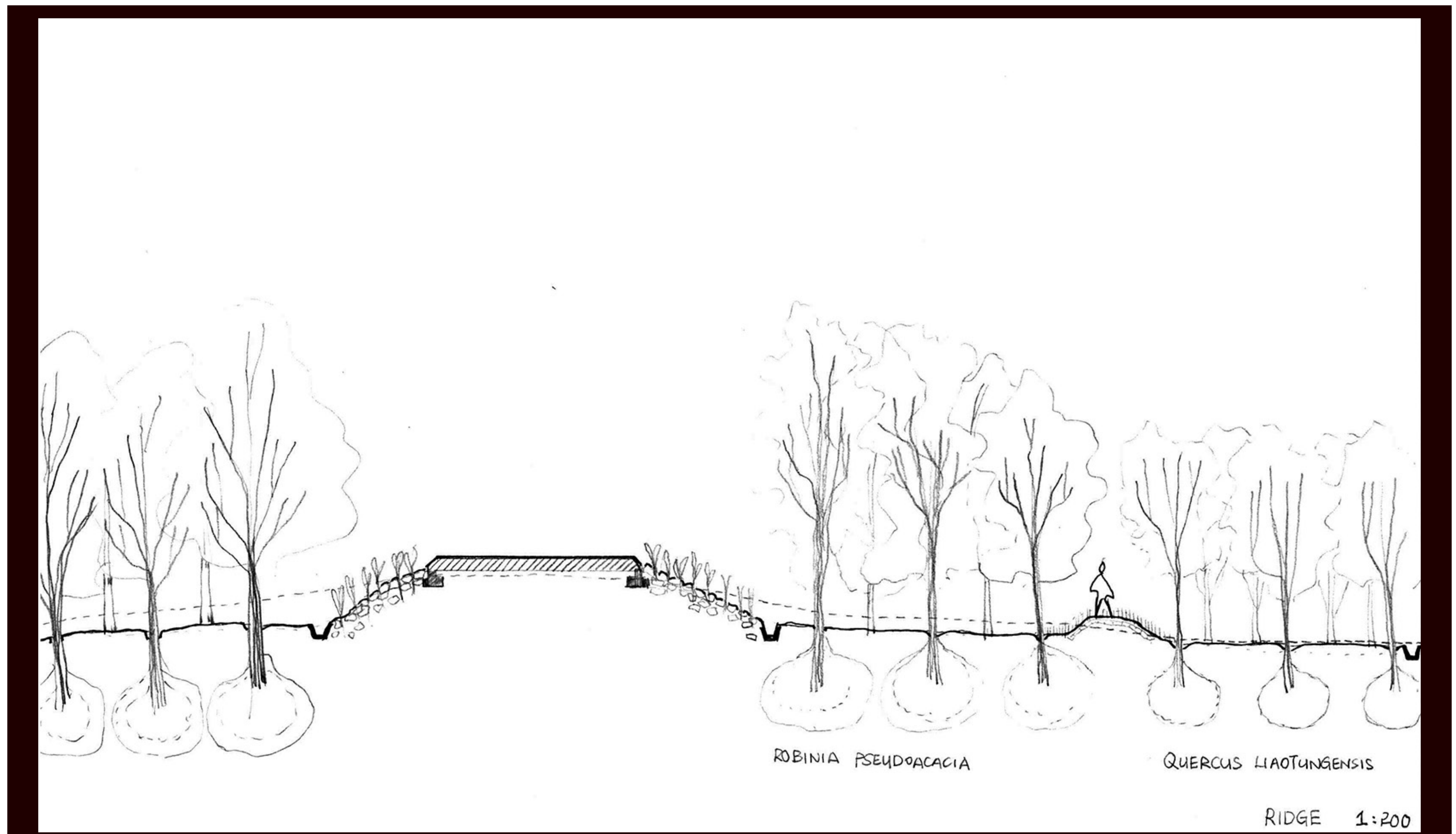
2.1.2. Vegetated Landform



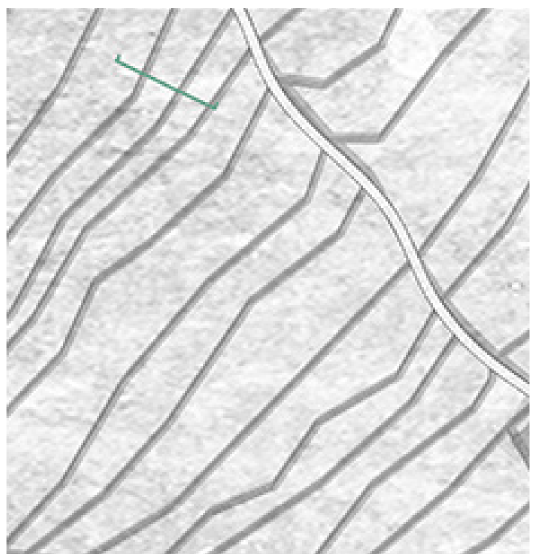
2.1.2-a Ridge Forest

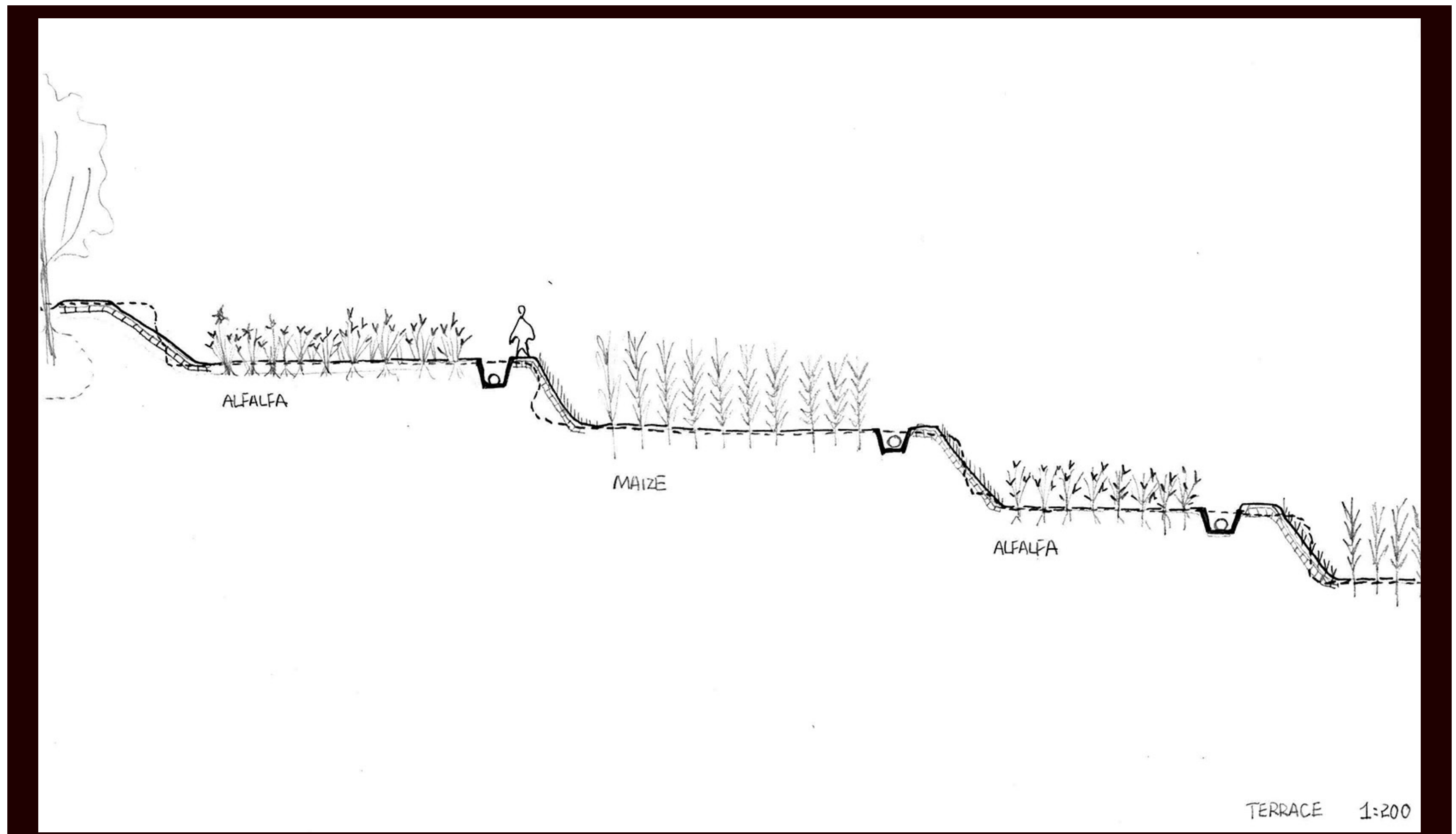




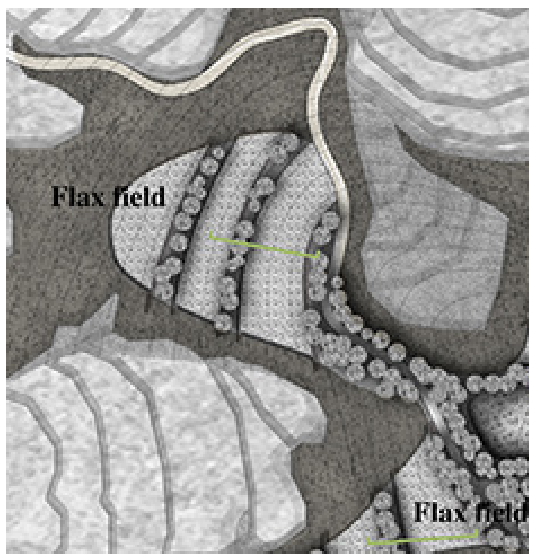


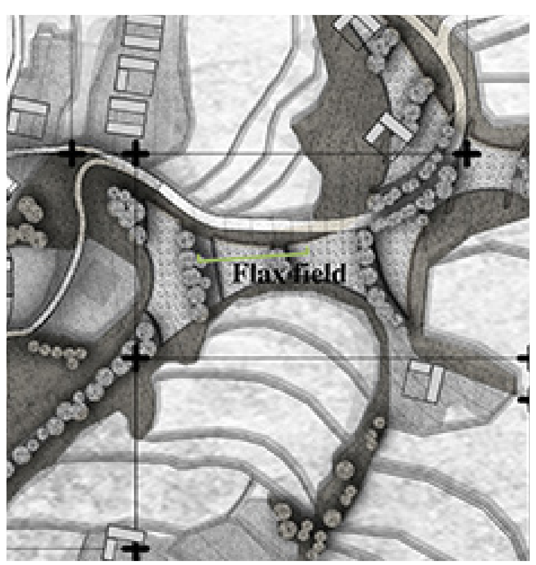
2.1.2-b Terrace Edge

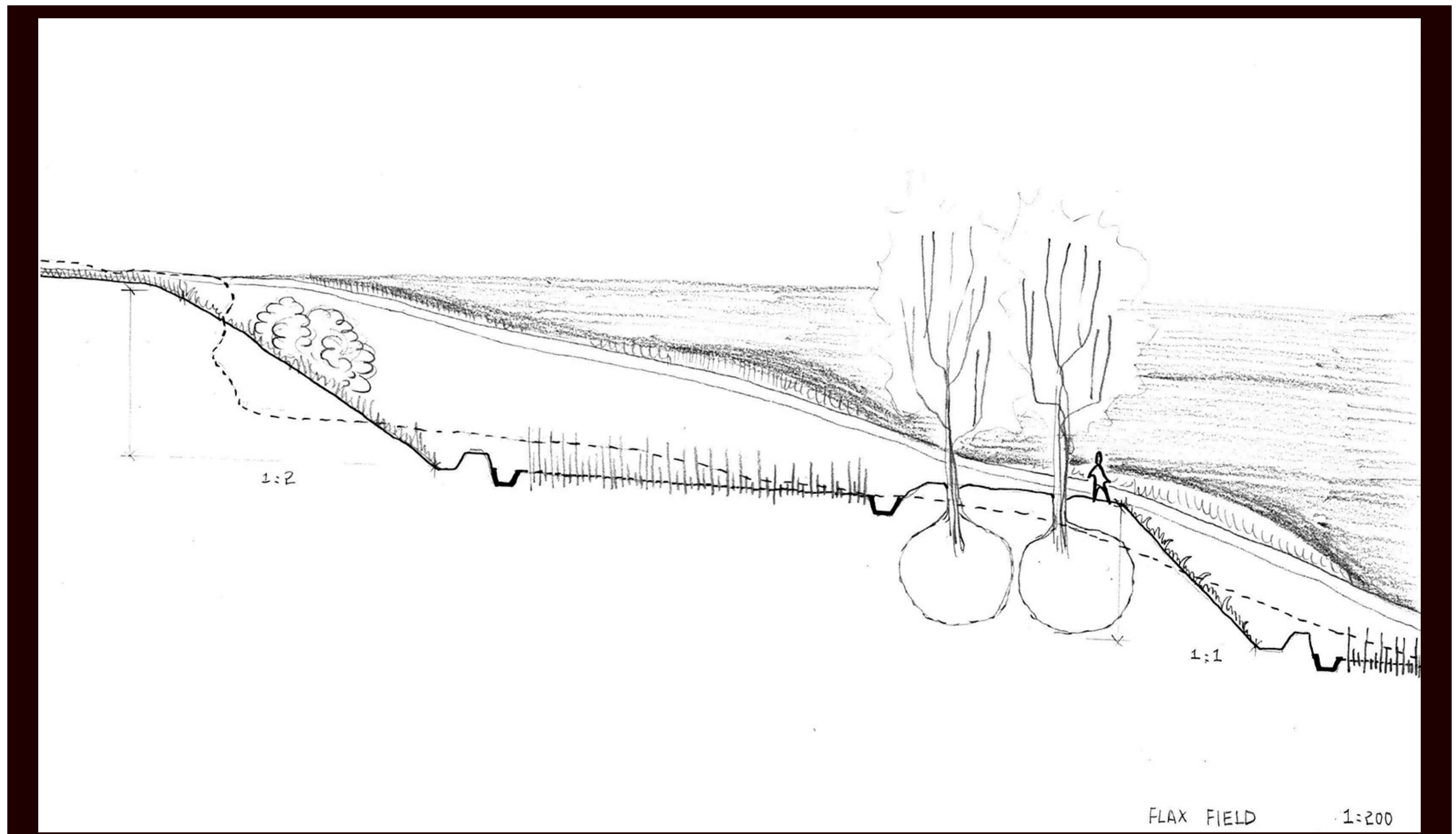




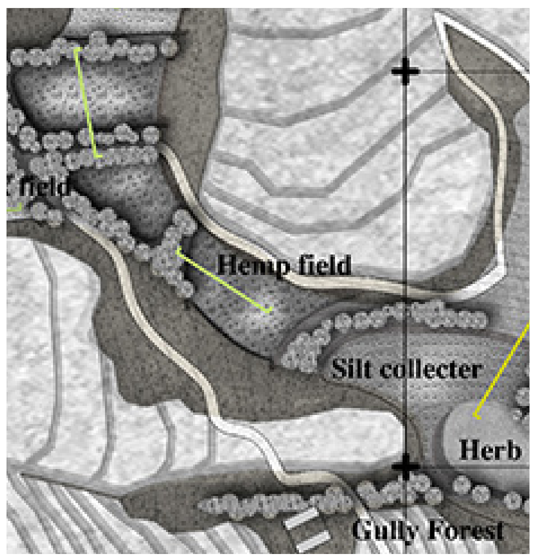
2.1.2-c   Flax Field & Grove

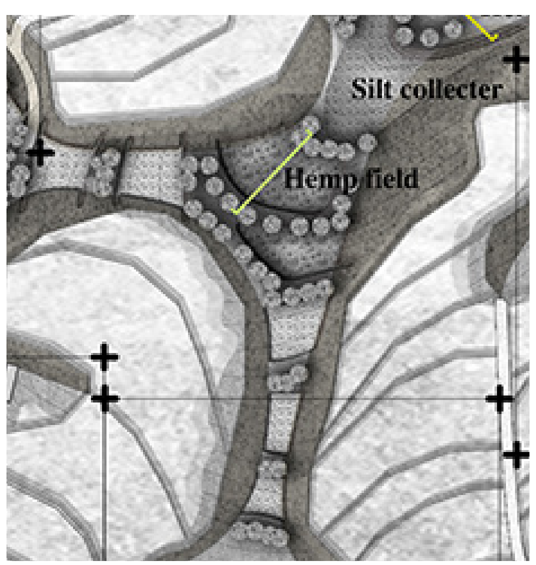


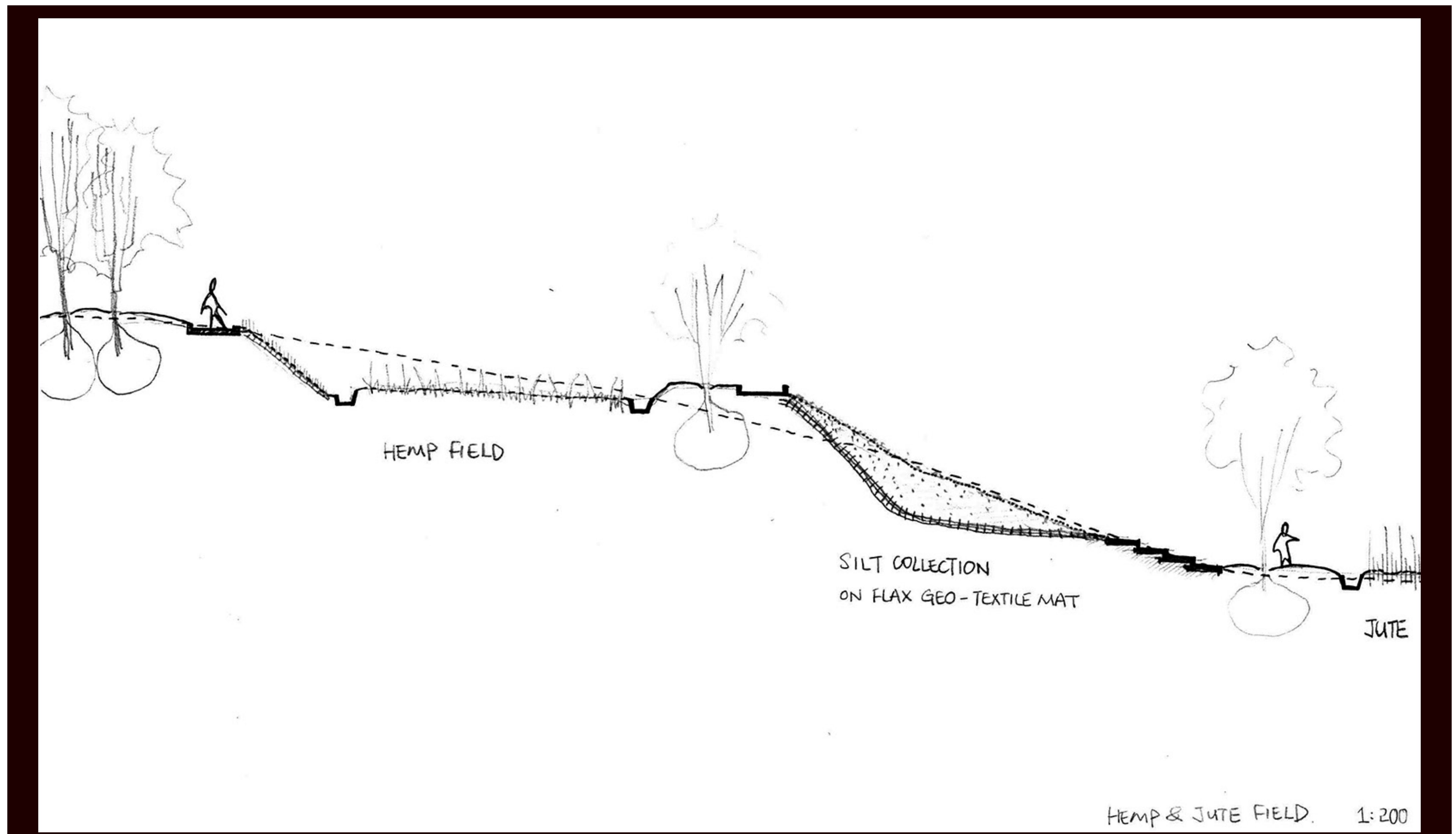




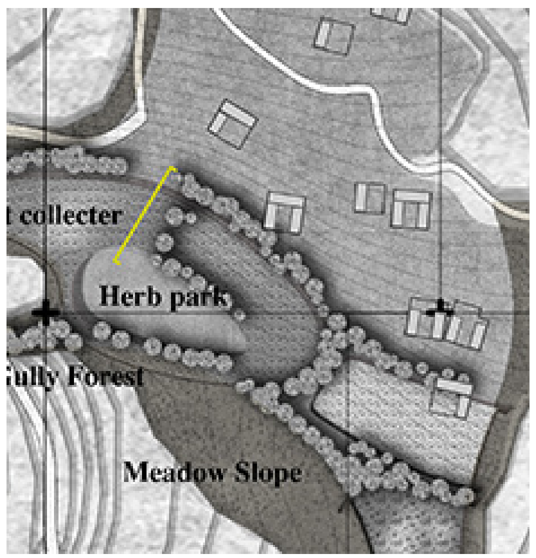
2.1.2-d Hemp Field & Silt Collector

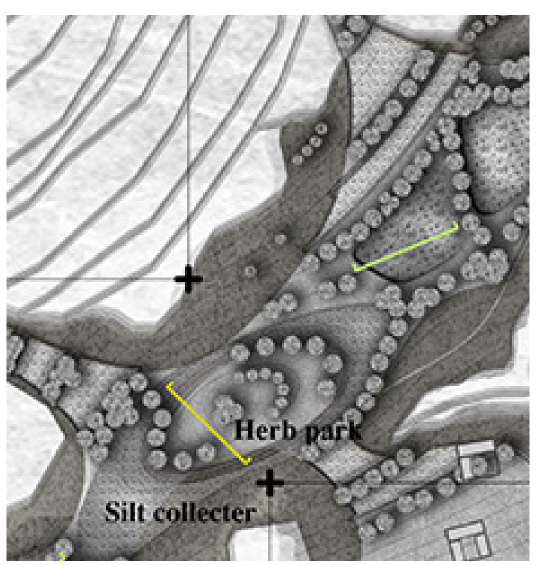


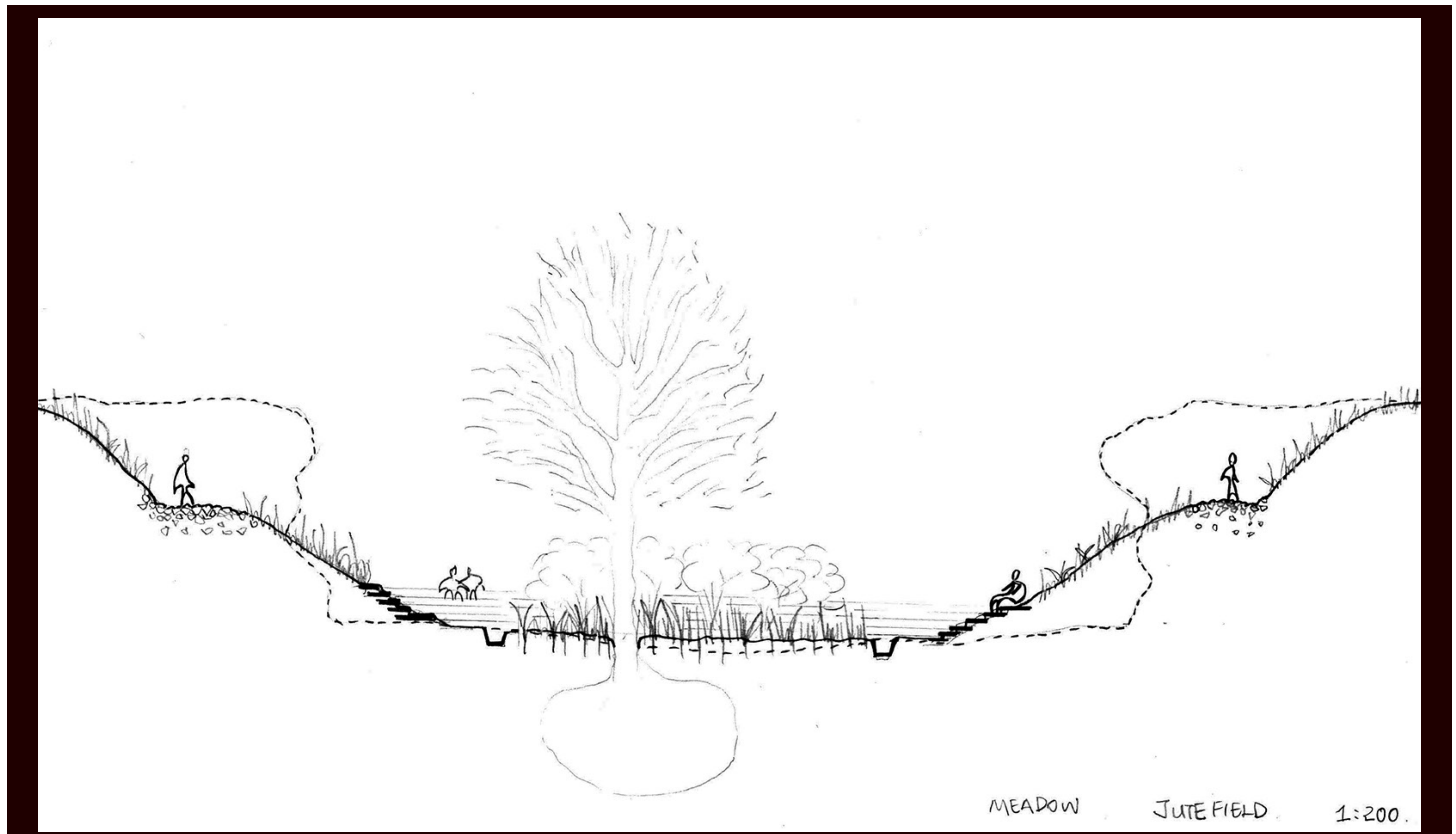




2.1.2-e Herb Park







225 m^2 = 15 m x 15 m

Reducing exposed loess section, reducing exposed dwelling wall, and making soil supply self-sufficient are the strategy for designing new dwellings. Five types are introduced.

The flat type **(A)** is designed for a piece of flat land, digging down 1.5 meters and building up.

The shallow slope type **(B)** is designed for slopes between 1:3 and 1:2, digging into the slope, retaining the interior, and building the roof.

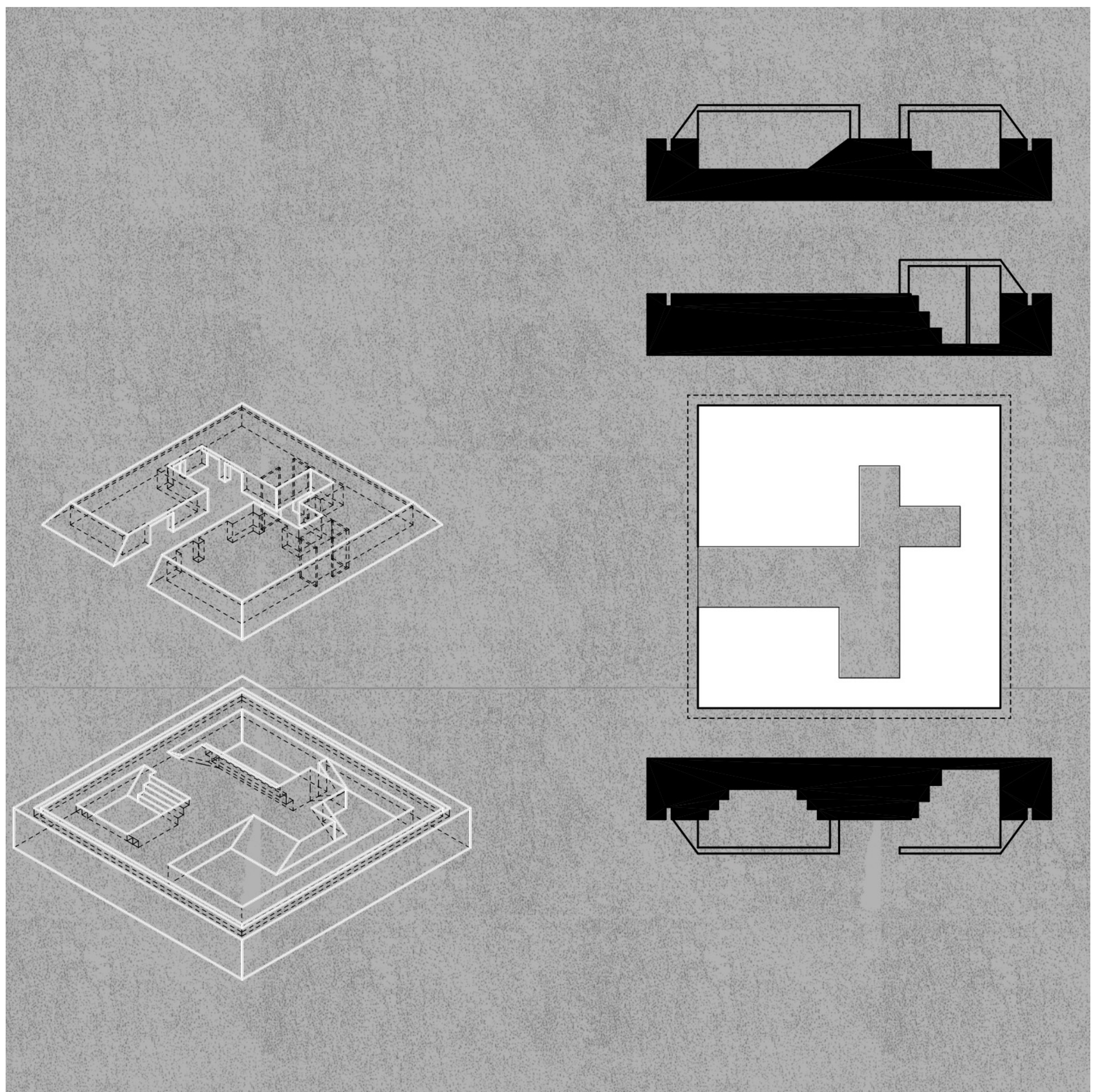
The medium slope type **(C)** is designed for slopes between 1:2 and 2:3, digging into the slope so that part of the dwelling is embedded into the slope with an arched structure and part is built with roofing.

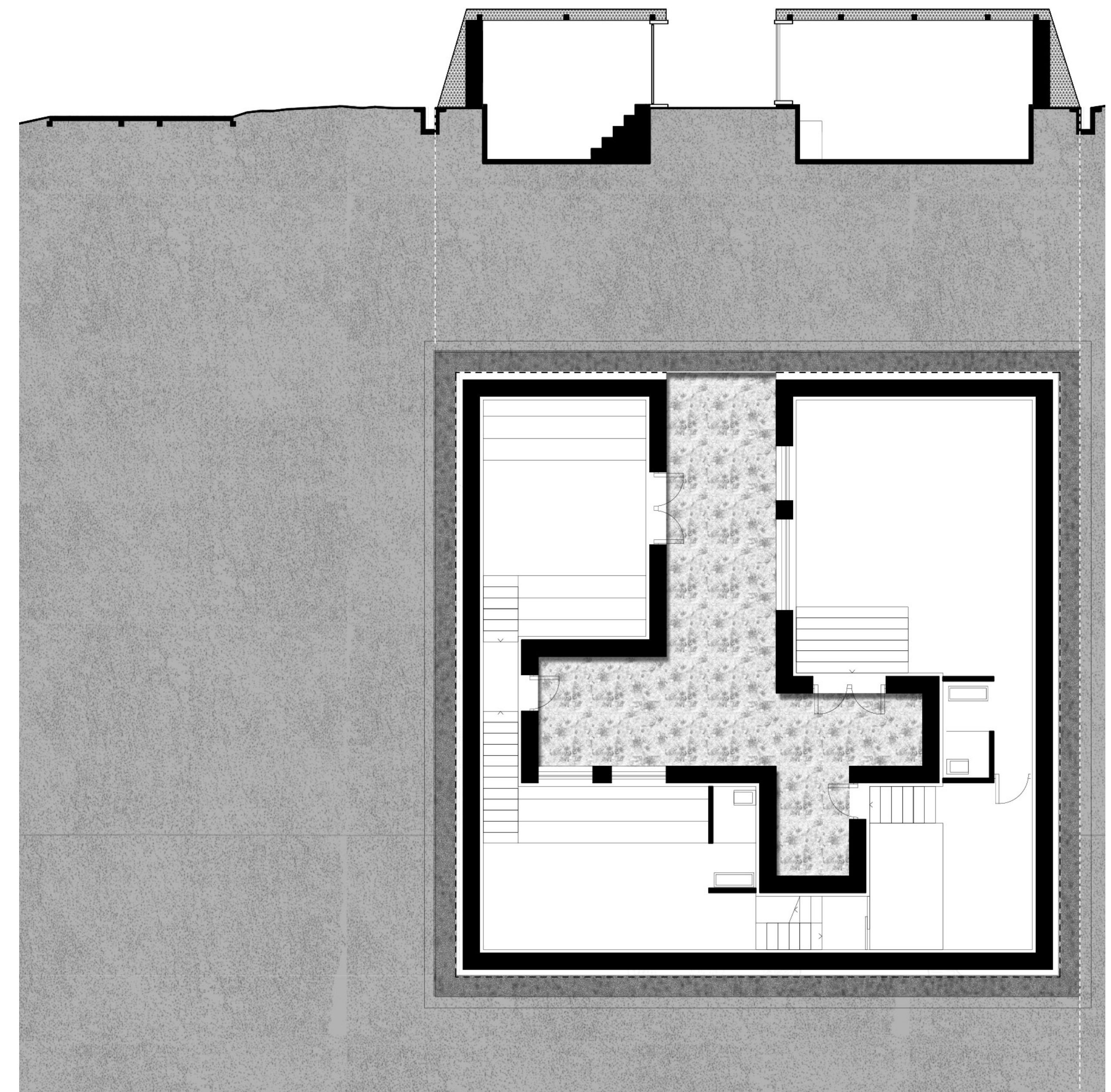
The steep slope type **(D)** is designed for slopes between 2:3 and 1:1, with the dwelling fully embedded into the slope.

The step type **(E)** is designed for cuts steeper than 1:1, grading the cuts into stepped slope and building on the steps.

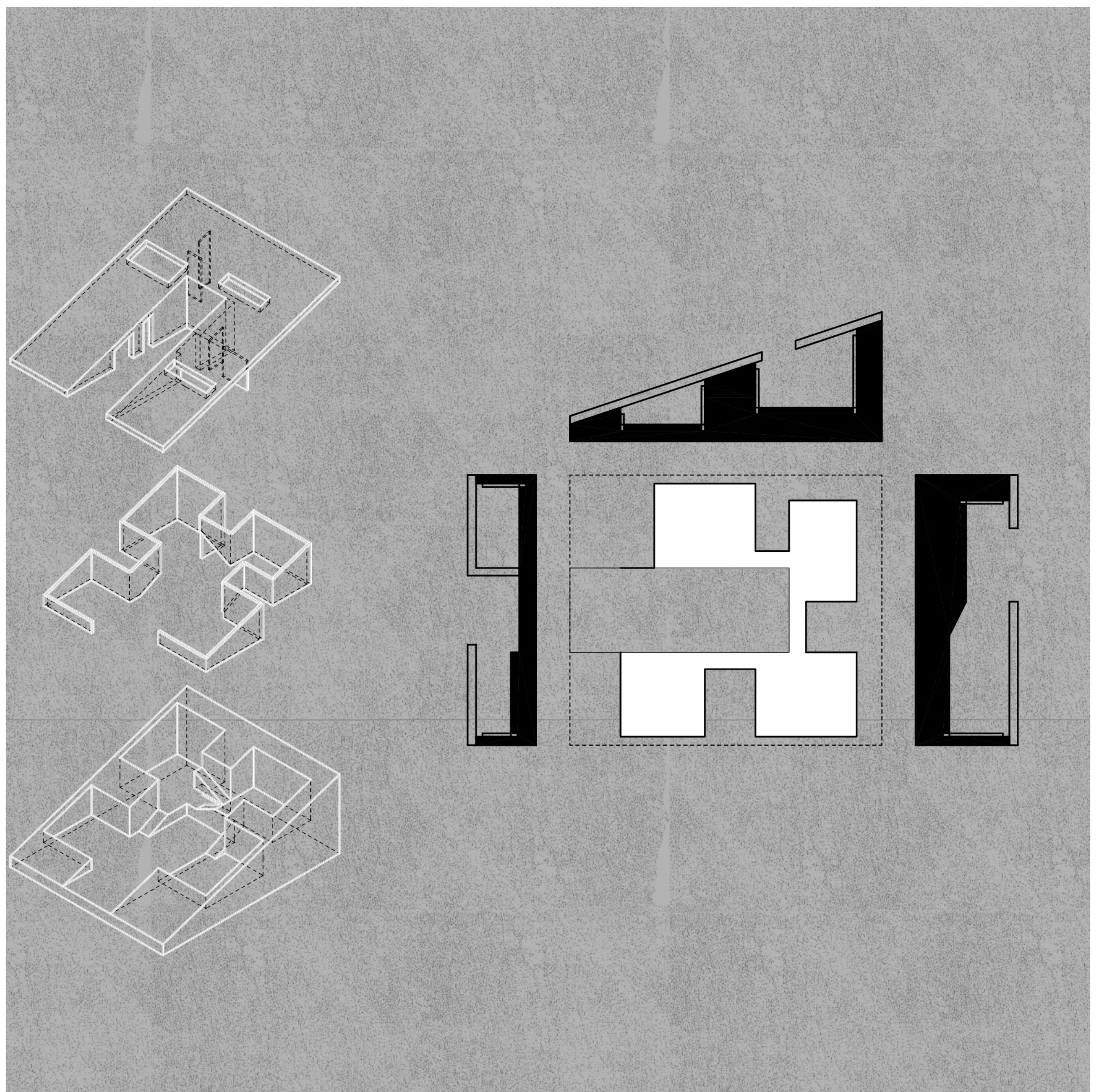
For all five types, the digging geometry, building geometry and roofing geometry become relatively independent, which gives flexibility to the built form and the landform. Meanwhile, each type can iterate different geometrical and spatial versions.

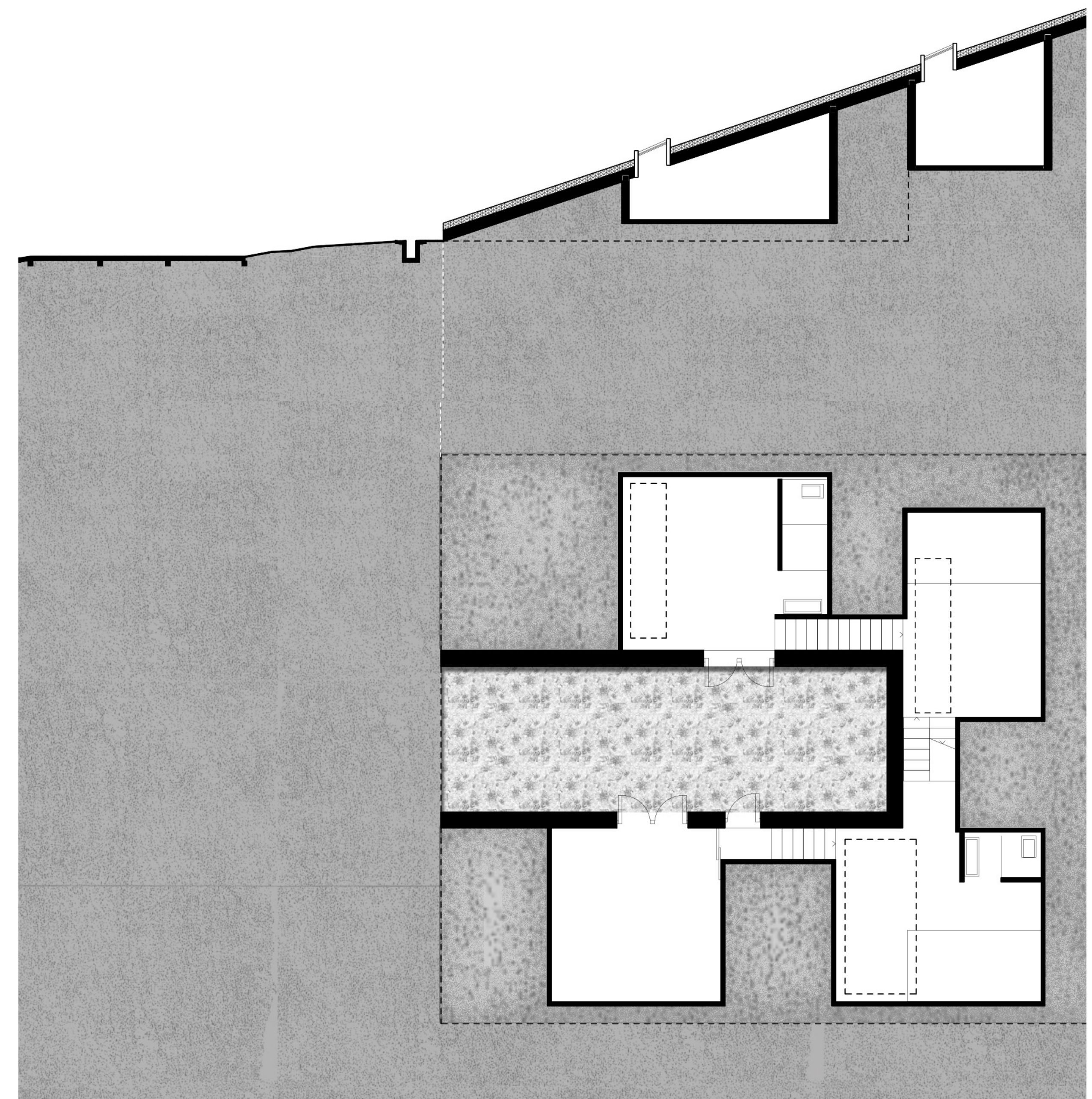
2.2.1. Type A (**Flat to Slope 1:3**)



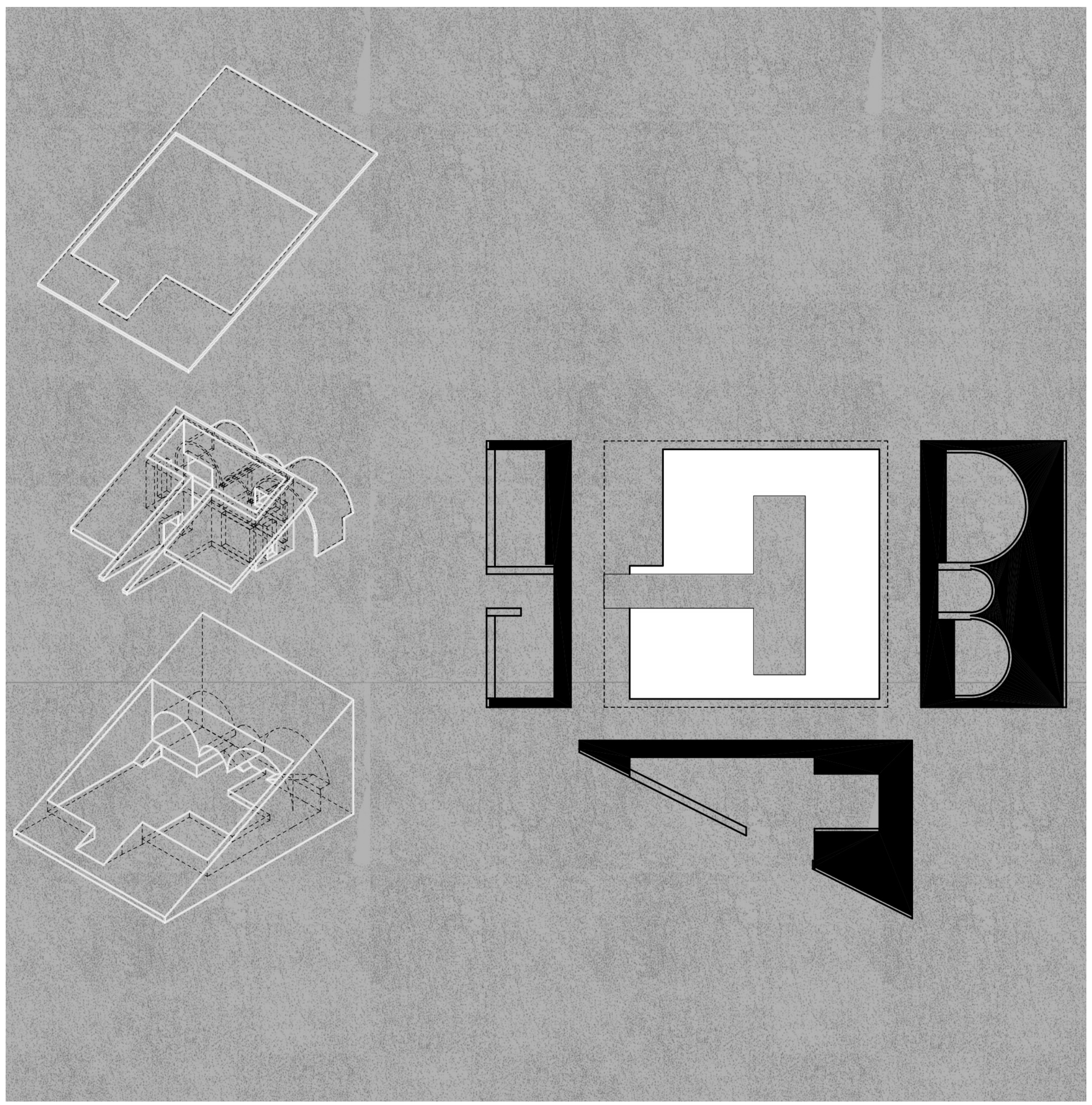


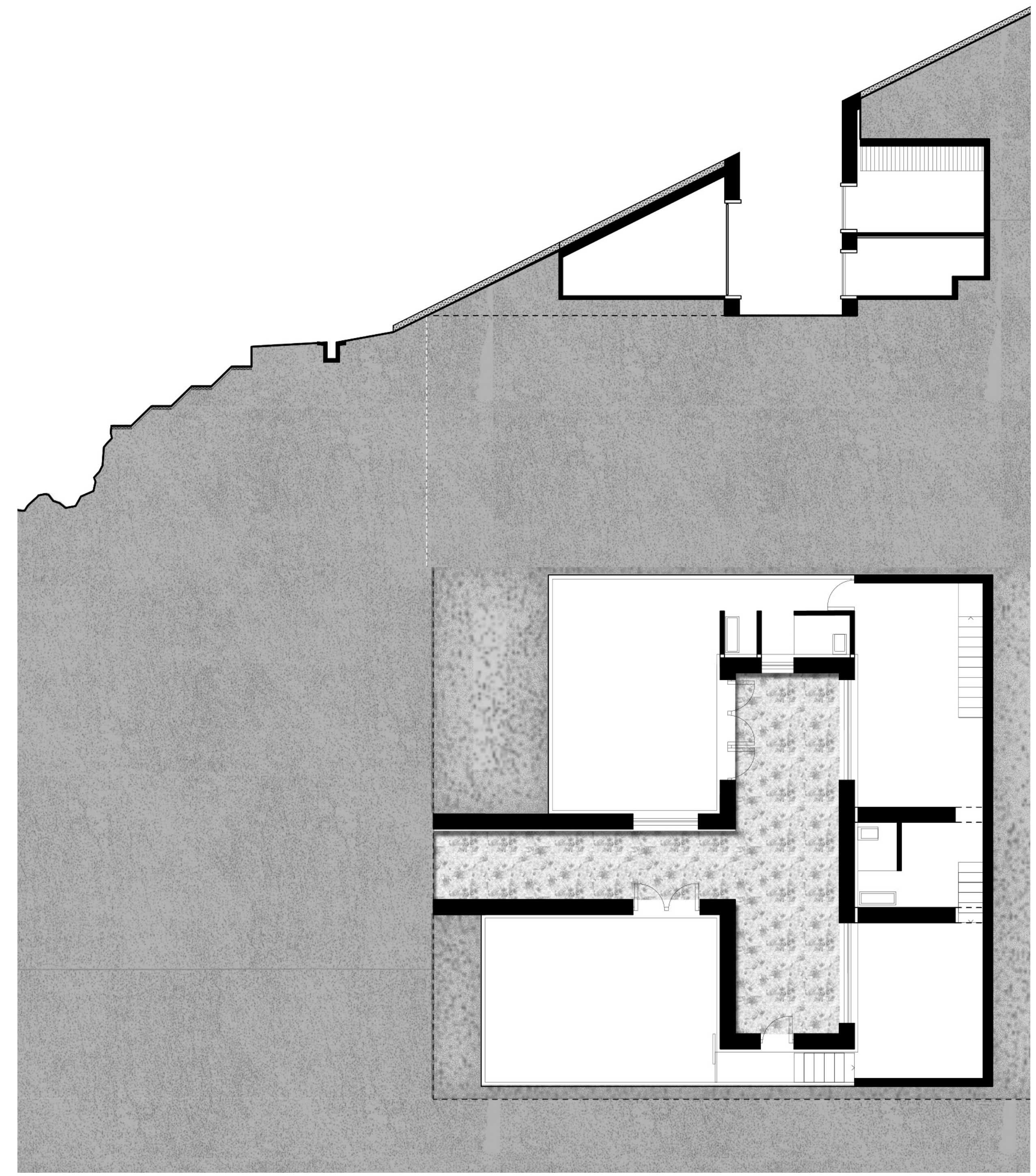
2.2.2. Type B (**Slope 1:3 to 1:2**)



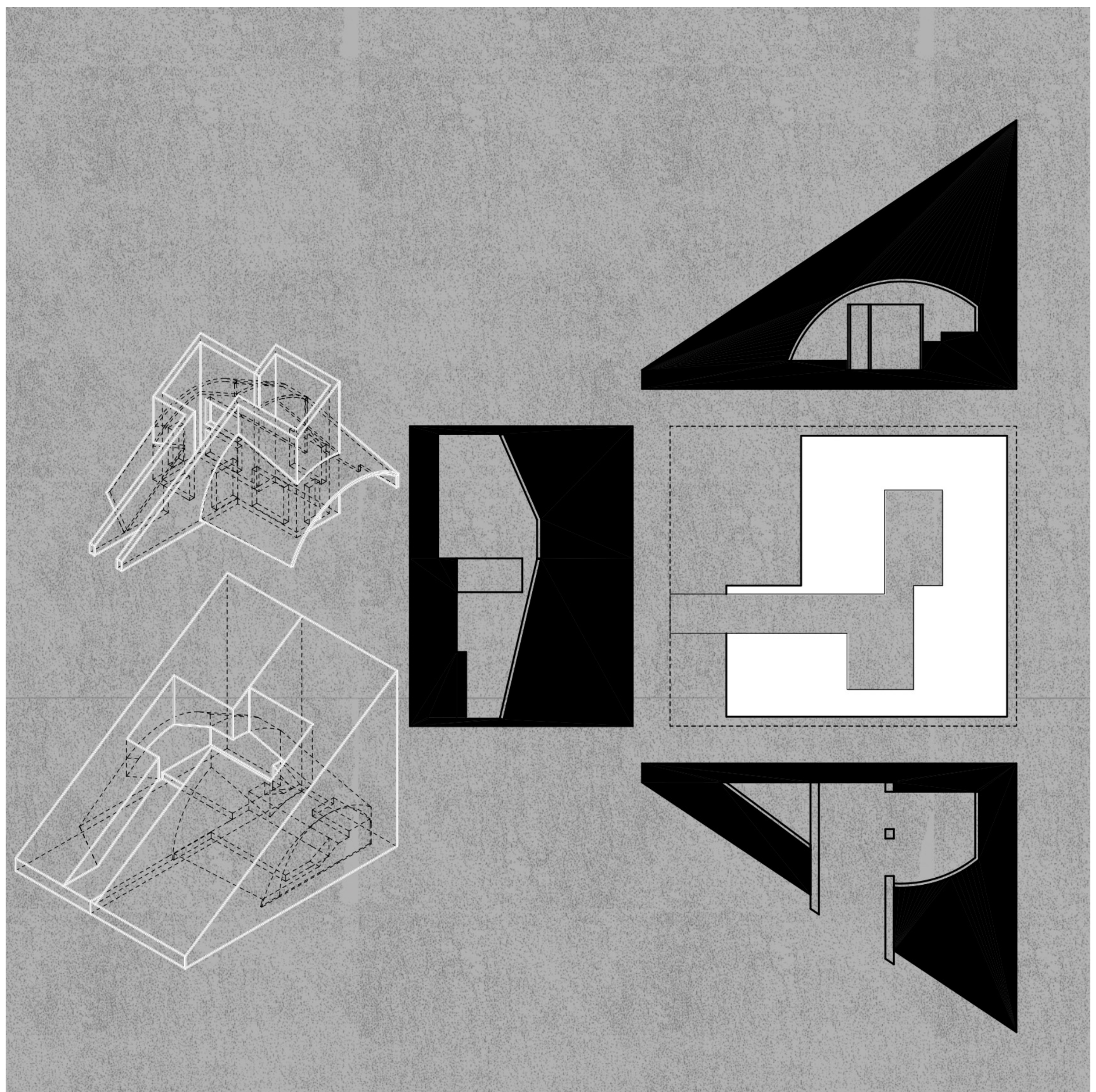


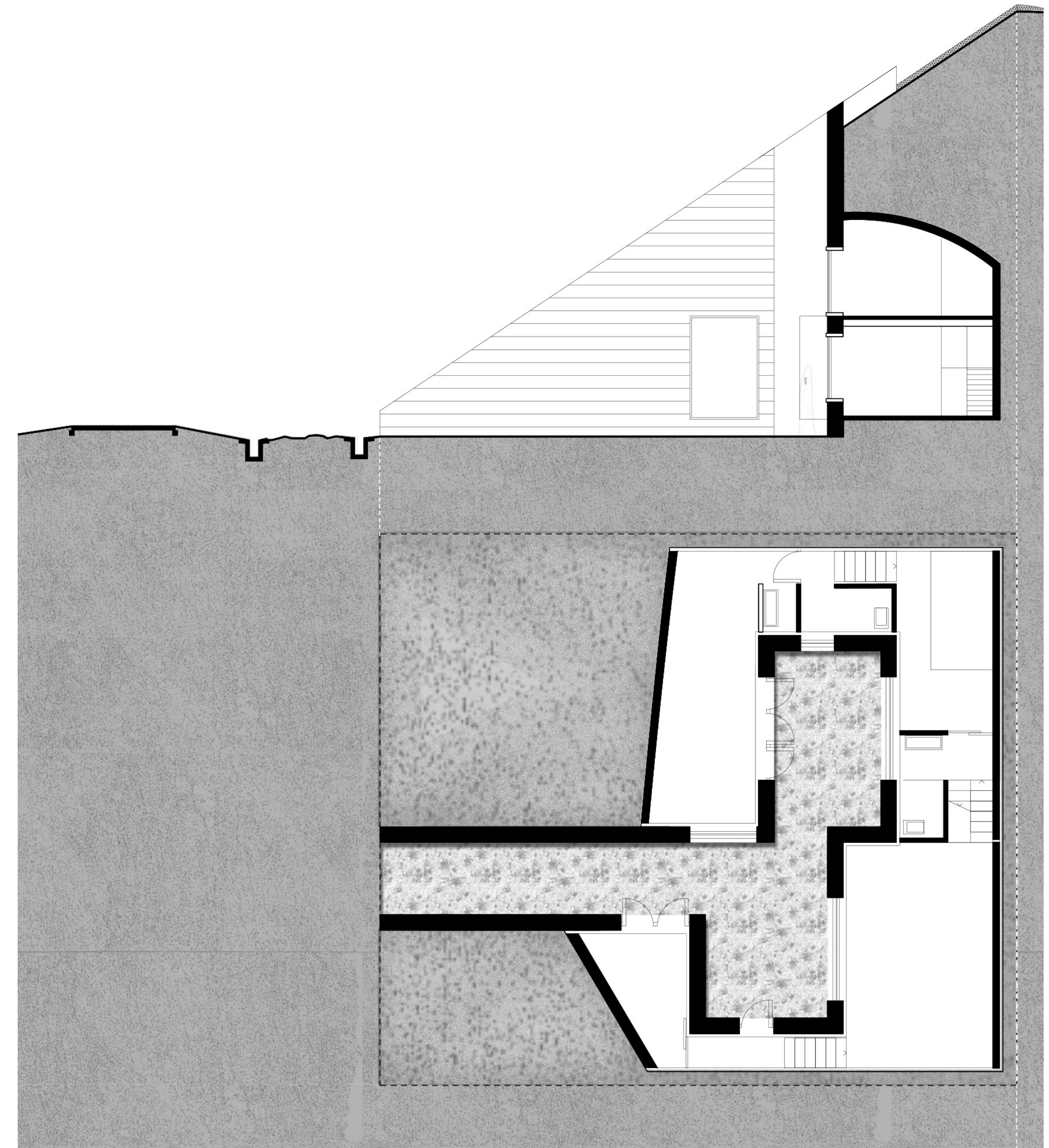
2.2.3. Type C (**Slope 1:2 to 2:3**)



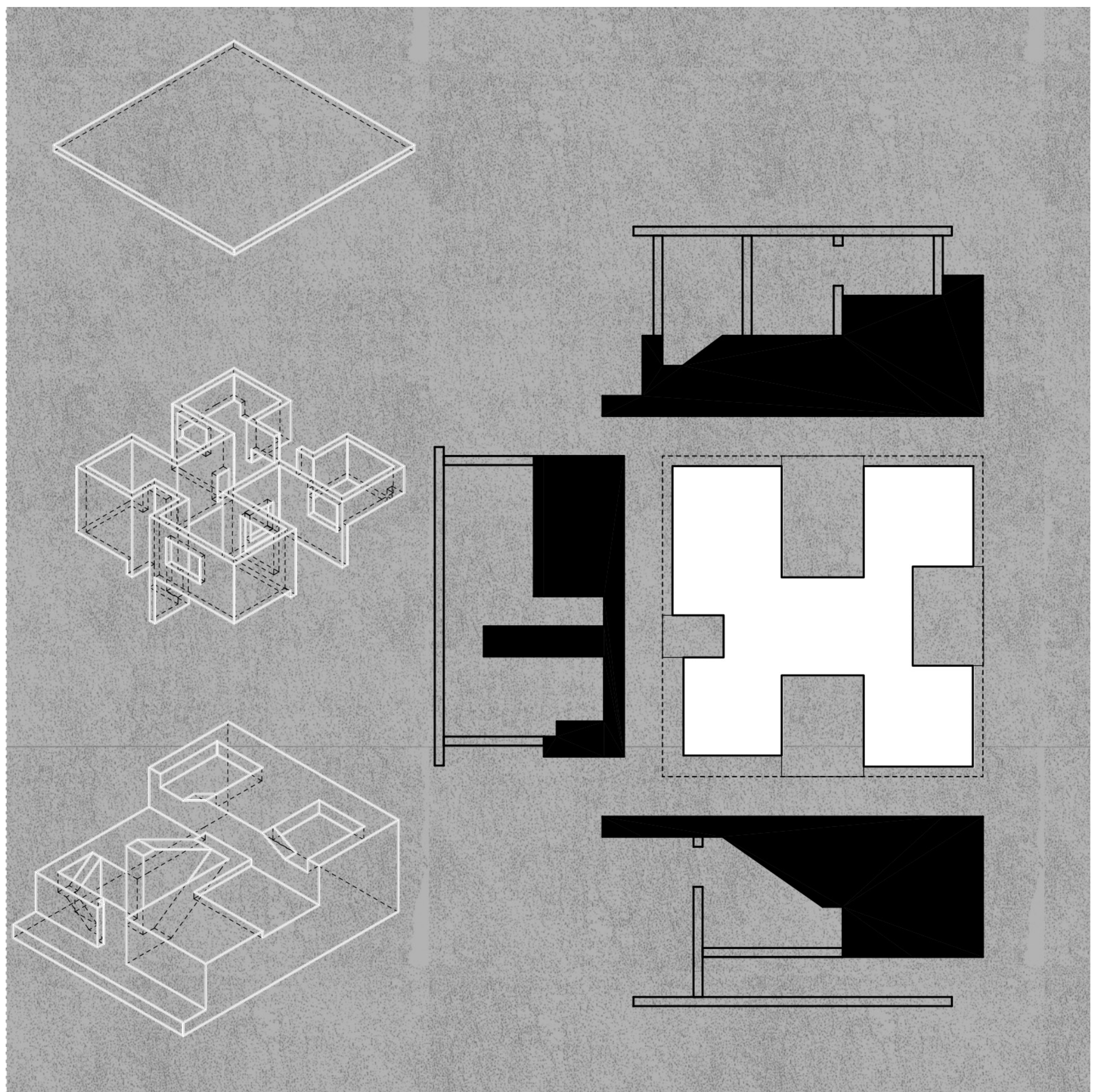


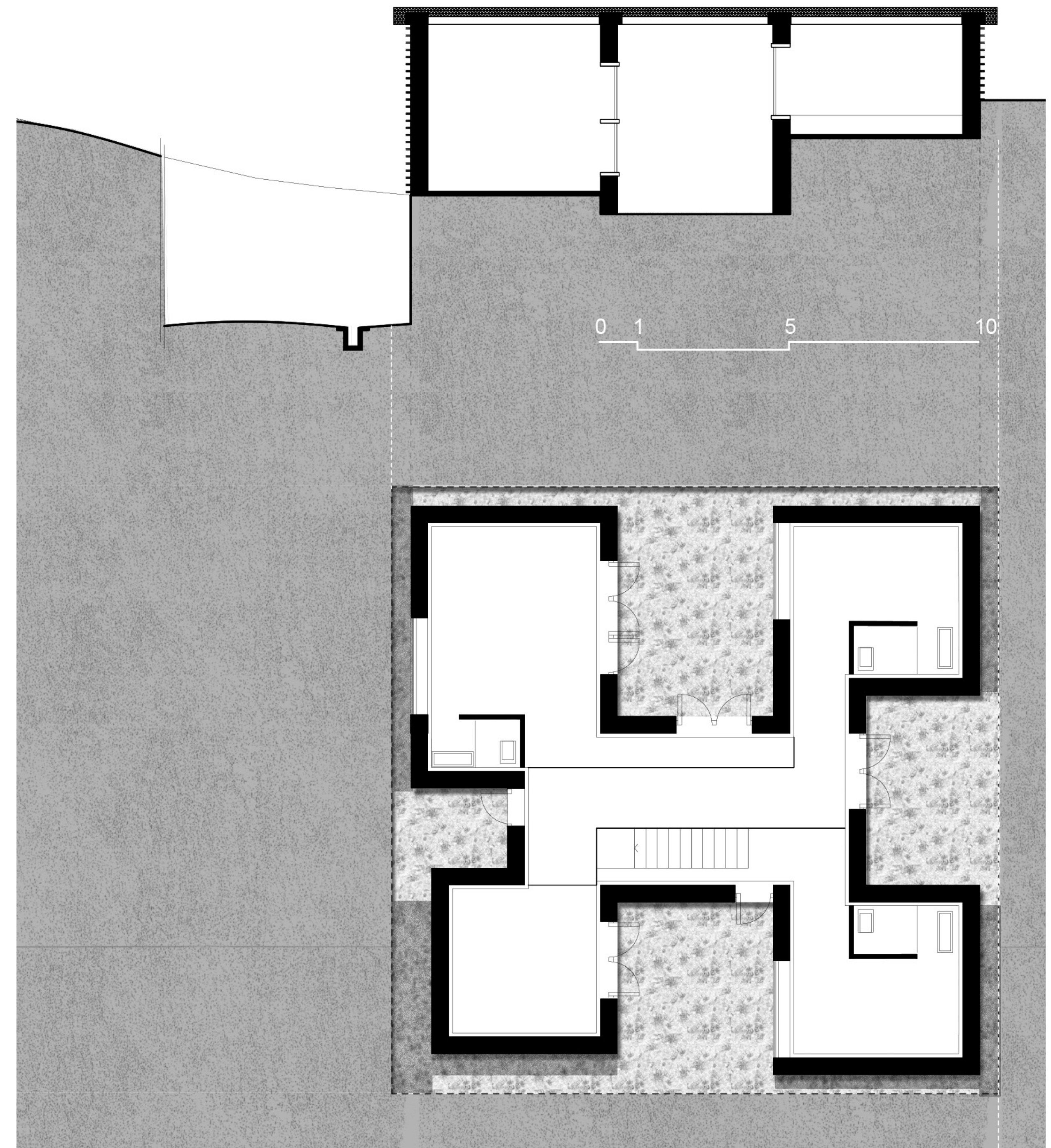
2.2.4. Type D (**Slope 2:3 to 1:1**)



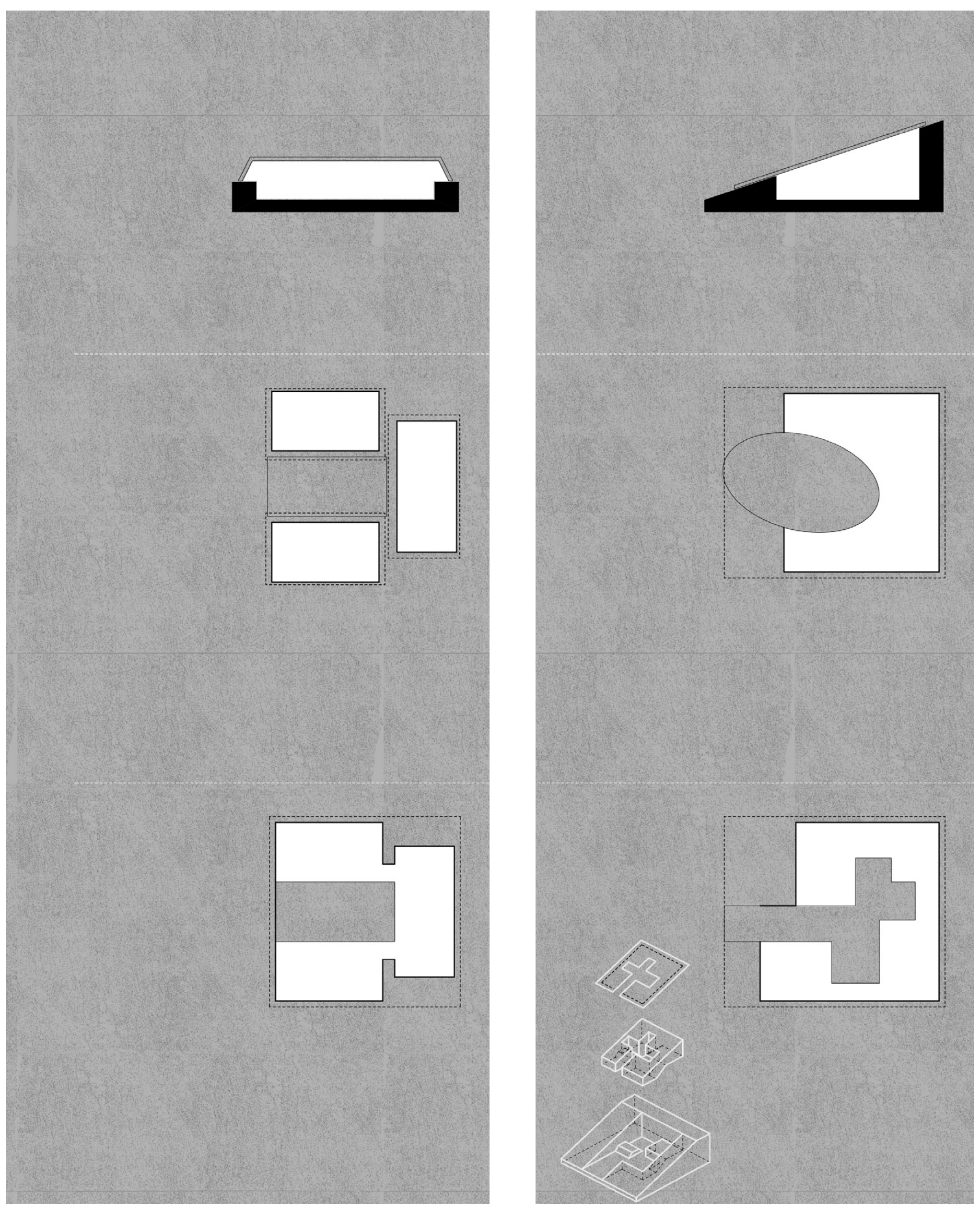


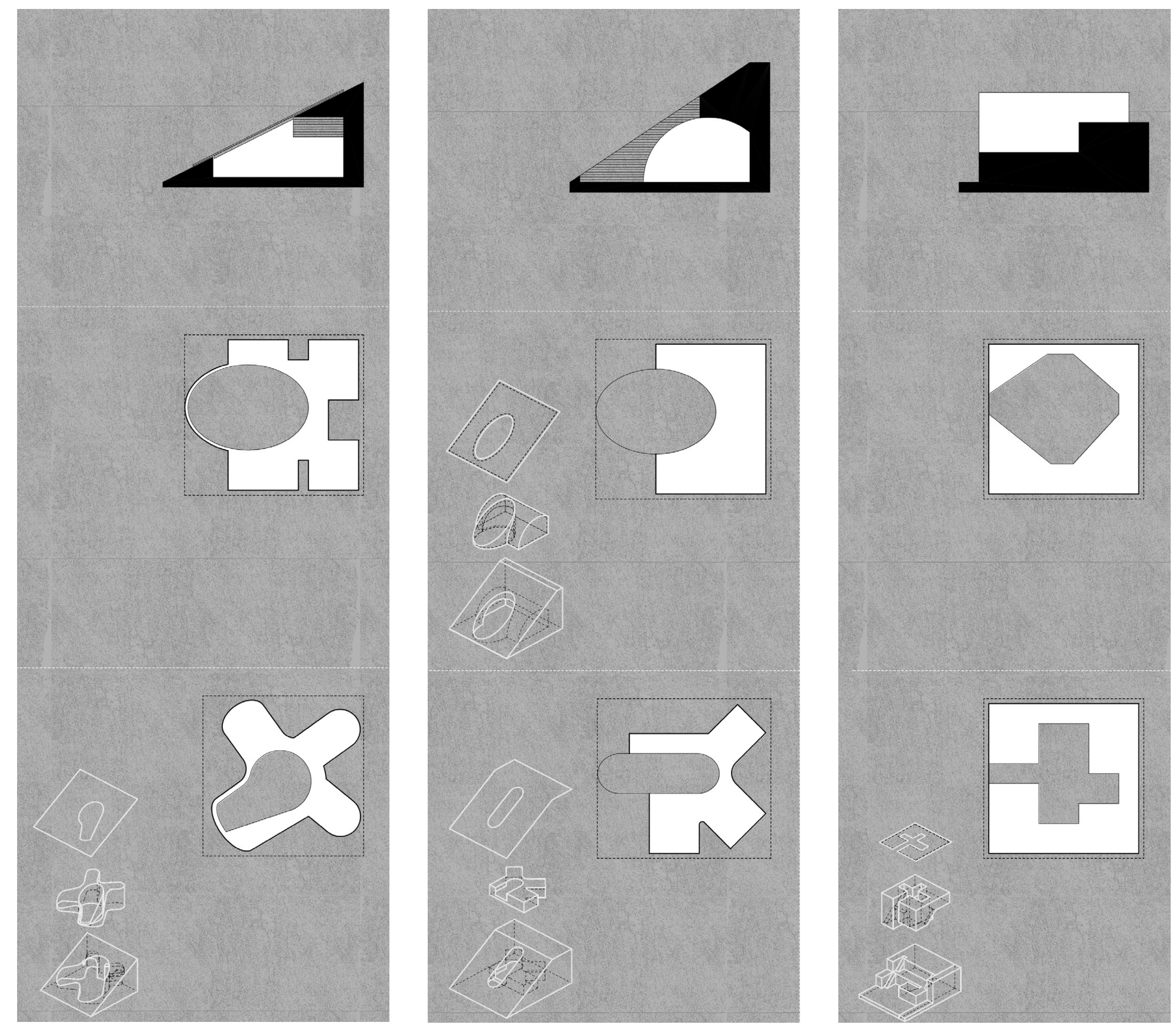
2.2.5. Type E (**Slope 1:1 to Cut**)





2.2.6. Iteration





45cm x 200cm x 30cm
24cm x 12cm x 6cm

The construction system of a new dwelling type has three main parts: retaining wall/vault with compressed earth brick (CEB), façade wall with rammed earth, and roofing with fiber/straw composites. A combination of flax mat and clay plaster is used for interior finishing. Straw mats and low-fired bricks are used for exterior finishing to slow down façade erosion.

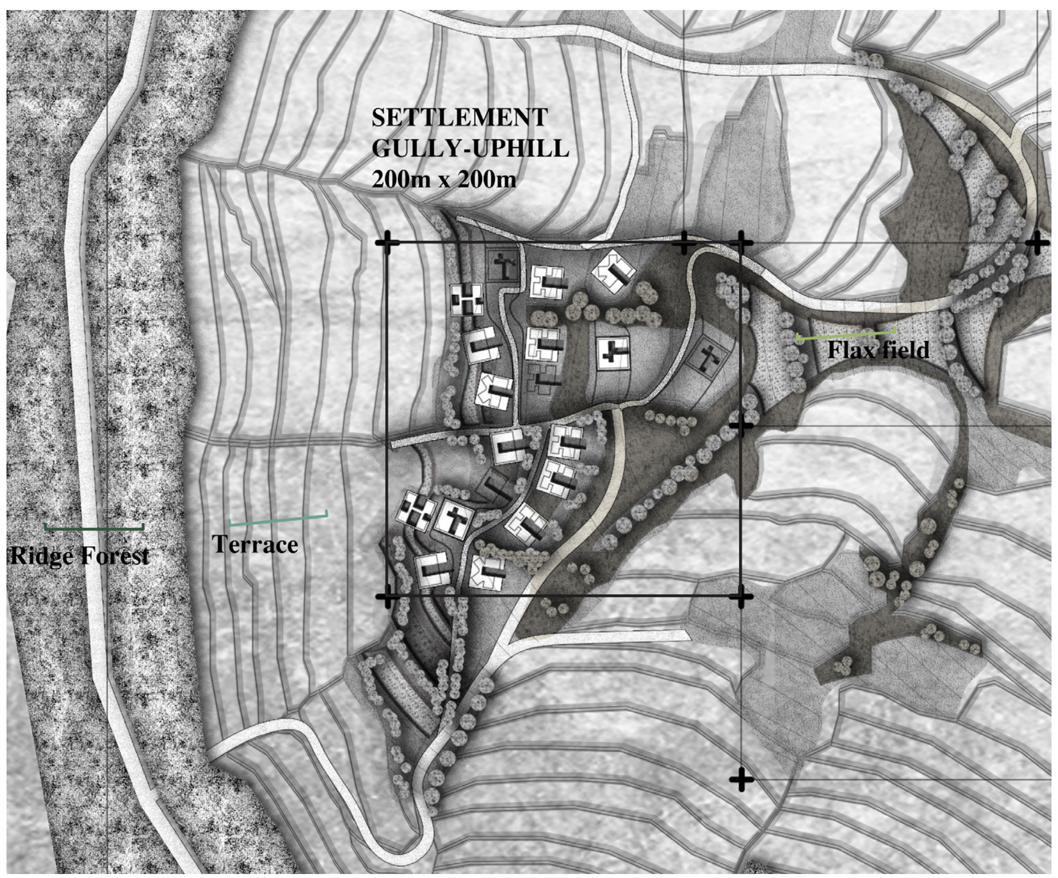
2.3.1. Type D (**Slope 2:3 to 1:1**) as example

Façade
rammed earth

Lintel
recycled timber

Retaining Vault
compressed earth brick

Roof
fiber/straw composites



40,000 m²
= 200 m x 200 m

The settlement design brings the principle of the vegetated landform and the dwelling types together. The pilot design is the first uphill-gully settlement, the starting point of soil erosion in a gully area. With five households living in the settlement, the landform of the settlement area had been gradually changed into cuts and gullies.

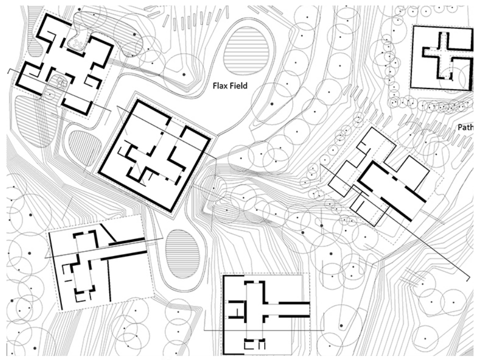
The settlement can be upgraded in **Phase I** by adding ten more dwellings. Those new dwellings can grade the slopes on their footprint and guide the vegetation strategy for the surroundings. For example, the courtyard of the step type can extend to the stepped terrace, in which flax planting can continue. The irrigation channel around the flat type can extend further and connect to the drains of other types. These drains link to agricultural fields to slow down the process of water loss. Community spaces and gardens can be formed.

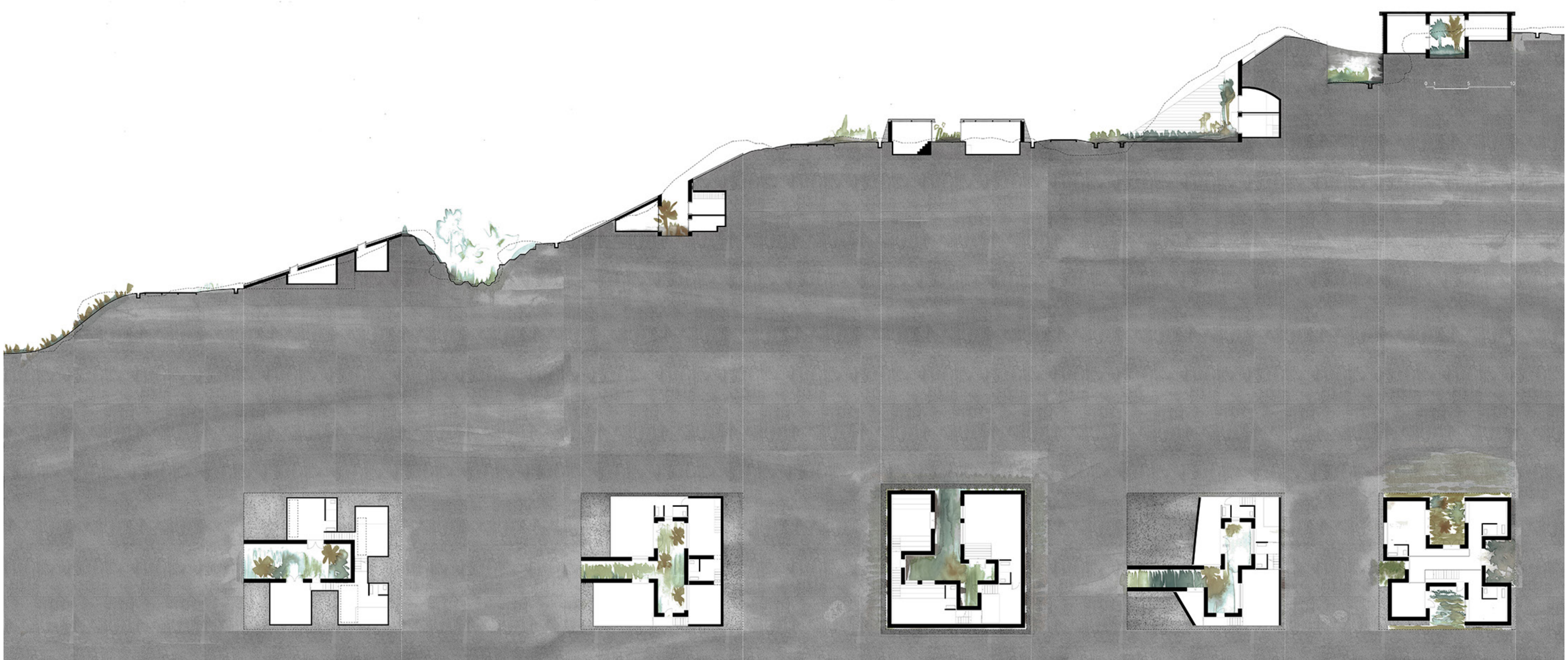
Eventually the settlement will be upgraded fully in **Phase II** by replacing the old five households to help meet the demand for replacing decrepit houses and for hosting younger families.

2.4.1. Phase I. Upgrading

2.4.2. Phase II. Replacing

2.4.3. New Landform and Built Form





Conclusion

This design thesis showed that considering the landform and the built form as a whole is the key to resolve the loess soil erosion problem. The scaling-in research approach from global to local was the key to understand the situation. The vegetated landform design using local species from the ridge to the gully / valley was the key to resolve current soil erosion. The new dwelling design reconciled the built forms with the landforms to reduce the exposed soil sections. The new dwellings do not exacerbate soil erosion in the future. The settlements were upgraded in phases by reshaping the landforms and replacing the built forms. Such a settlement tripled the number of households to help meet the demand for replacing decrepit houses and for hosting younger families. A new sense of community and a new joy of rural living were created.

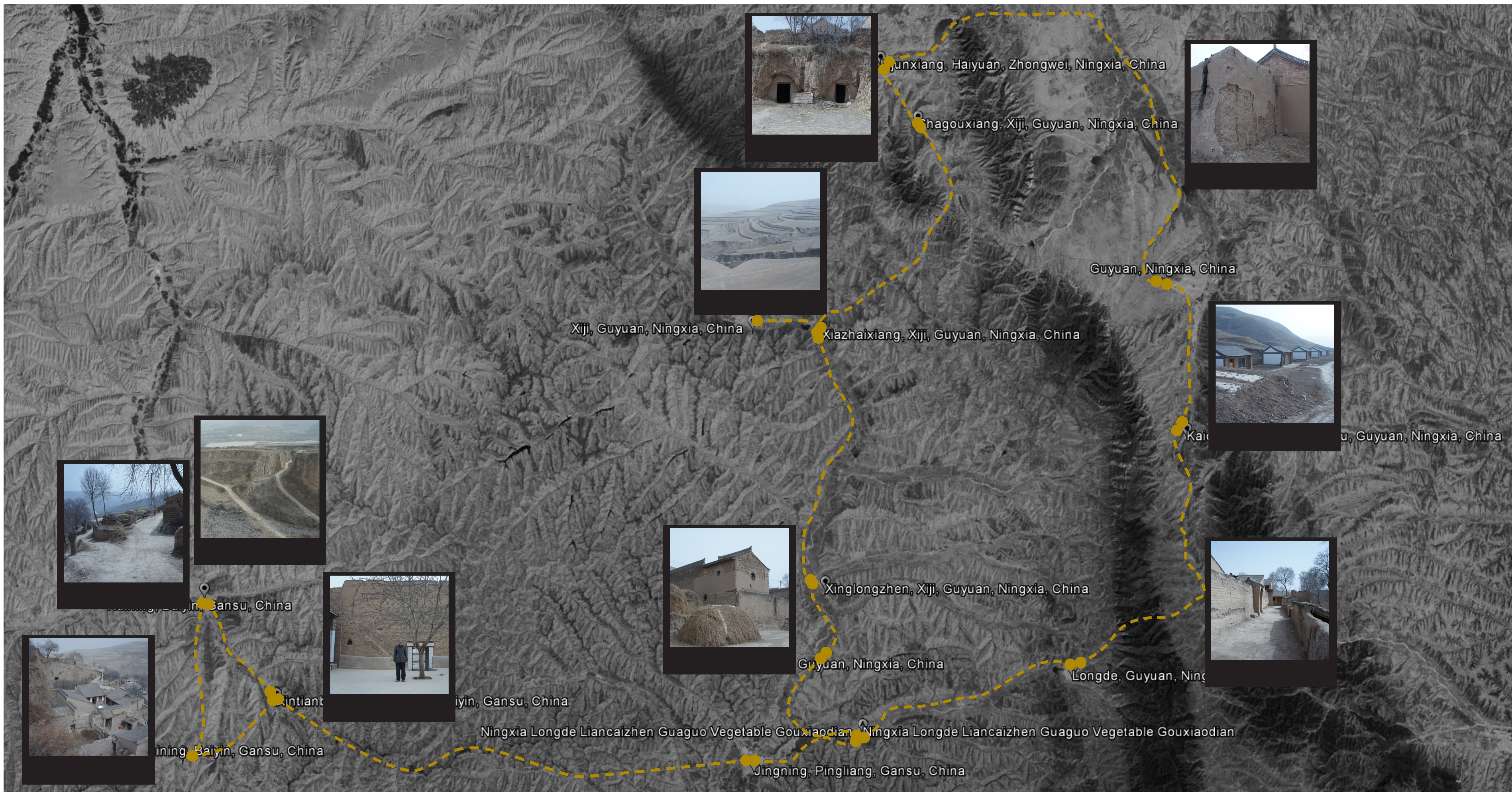
The future of this research and design will be about the evolution of the designed landforms and built forms, and the construction test on site. Pilot project will be initiated and hopefully be implemented in the west Loess Plateau.

Bin Li. May 22, 2014. Boston.



Biography

Bin Li, born 1987, grew up in Beijing. After high school studied architecture at the University of Hong Kong (HKU) and exchanged at Akademie der bildenden Künste Wien. Worked for a year at Community Project Workshop at the HKU on architecture design in rural China, and interned at Israeli International Conservation Center in Akko and at Vogt Landschaft in Berlin. Interested in landform and built form as a whole, especially raw earth as the shared substrates.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Xinglongzhen, Xiji, Guyuan, Ningxia, China
Gansu, China
Guyuan, Ningxia, China
Longde, Guyuan, Ning
iyin, Gansu, China
Ningxia Longde Liancaizhen Guaguo Vegetable Gouxiaodian
Ningxia Longde Liancaizhen Guaguo Vegetable Gouxiaodian
ining, Baiyin, Gansu, China
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Loess and Landscape


Village and Landscape 1

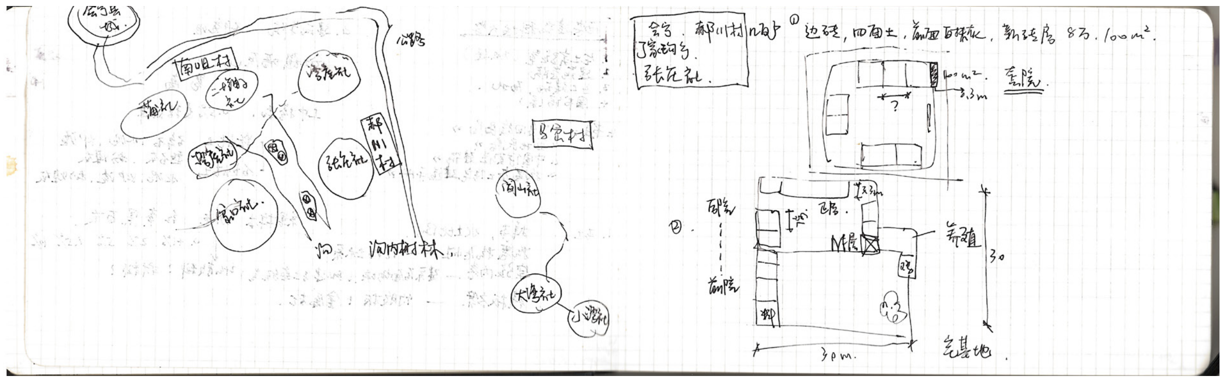

Village and Landscape 2

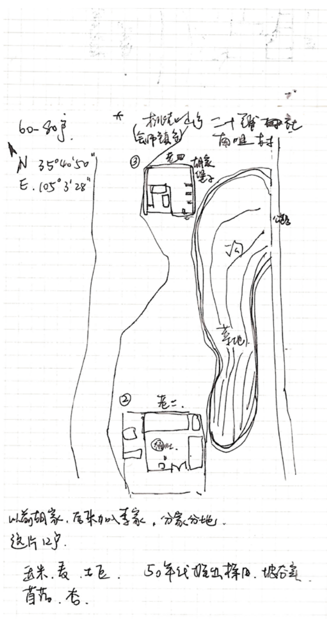
Adobe

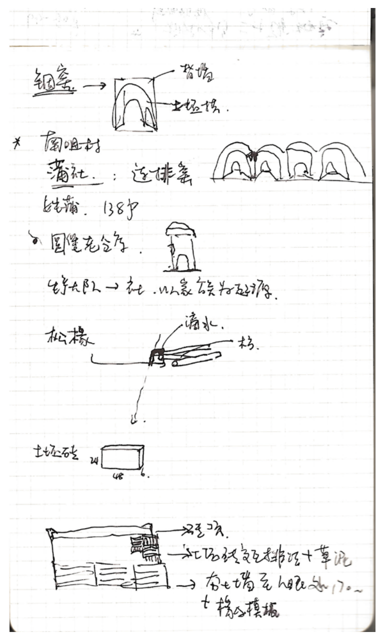
Rammed Earth

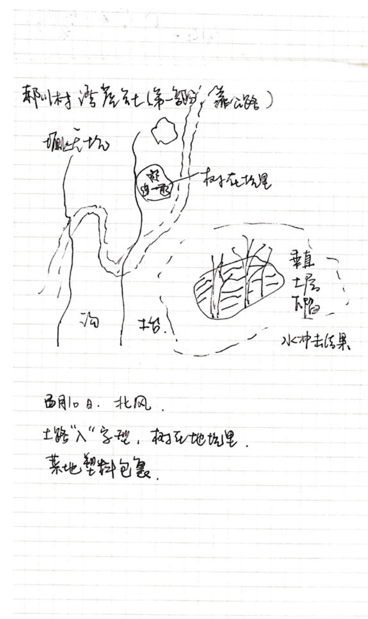
Combination

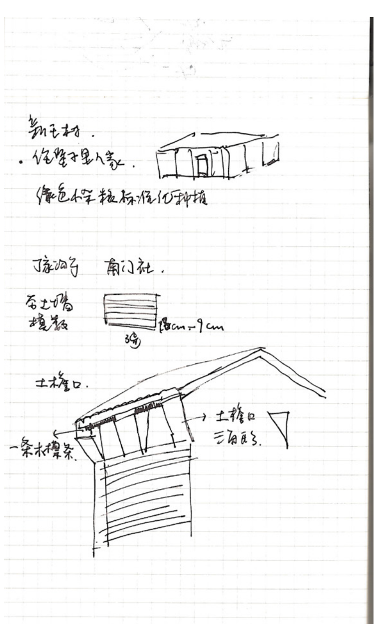
Straw

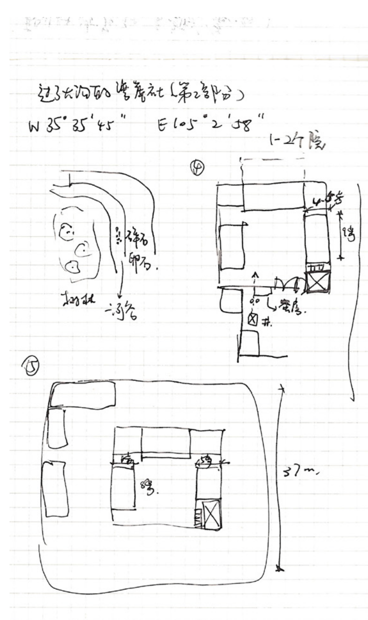


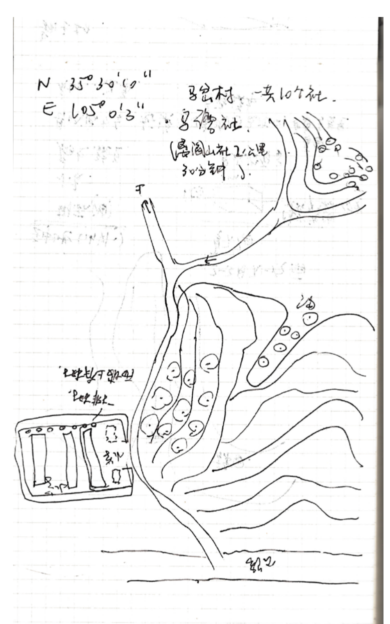


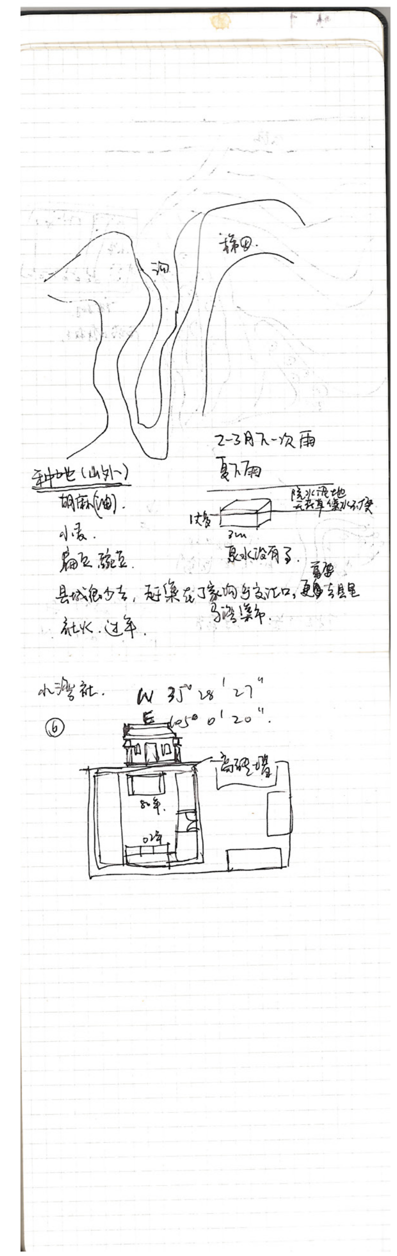


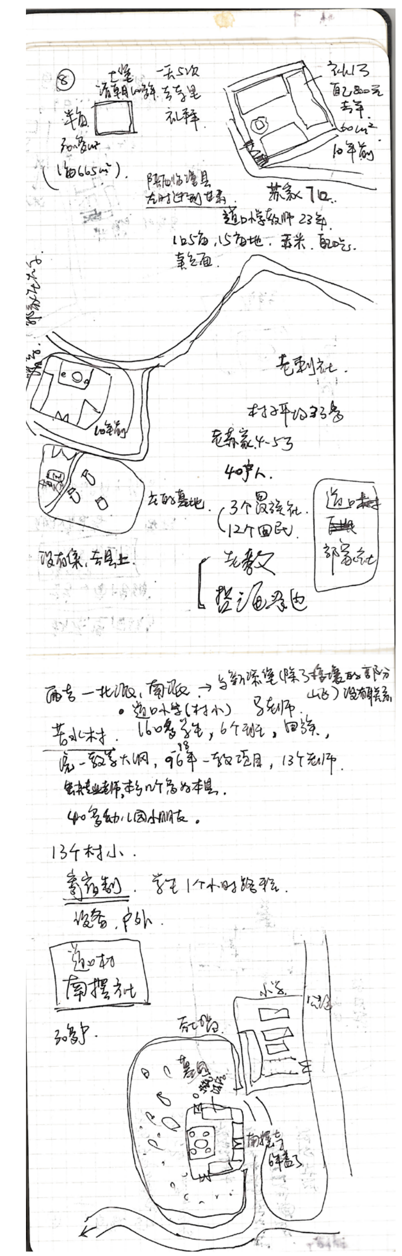


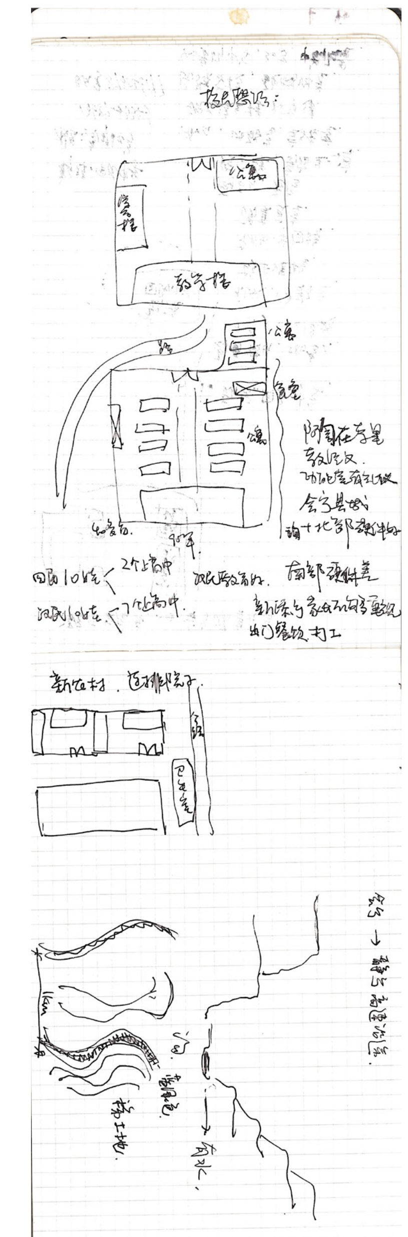




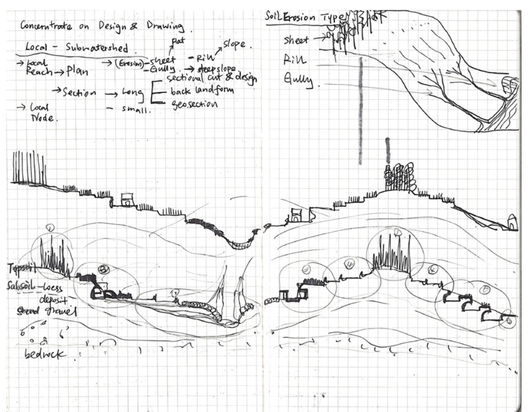


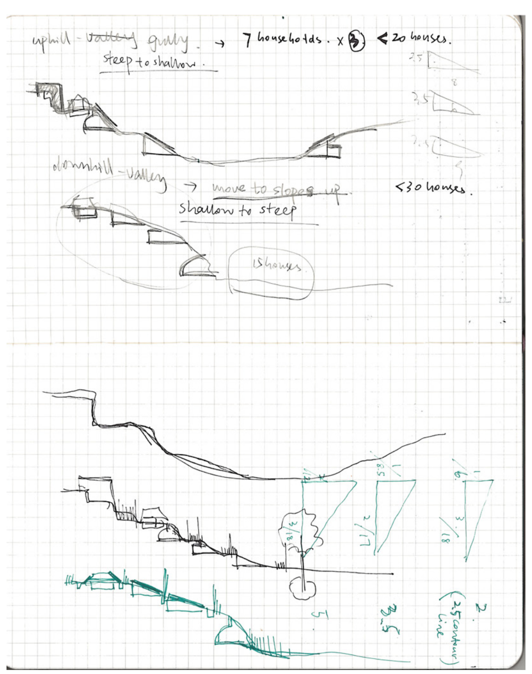


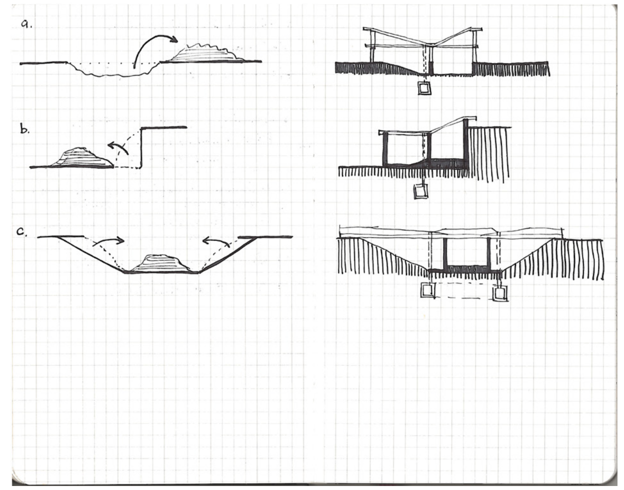


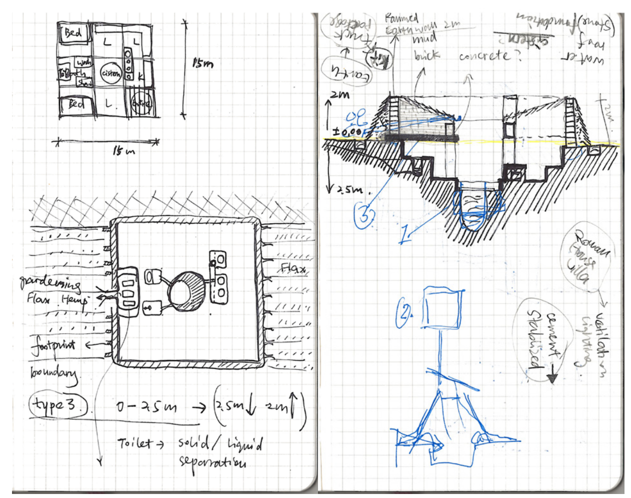


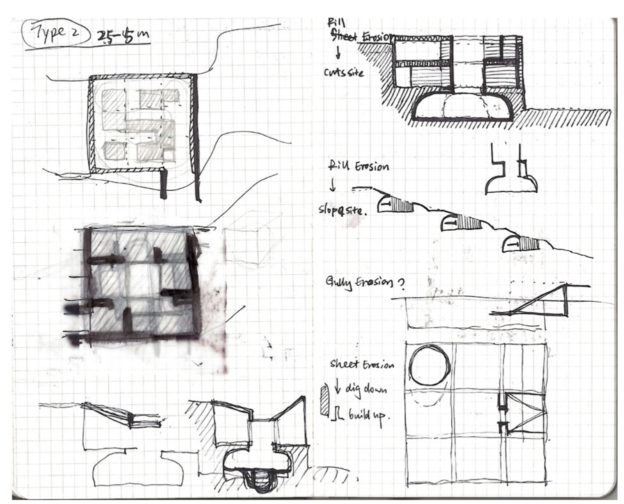
Appendix II **Working Skteches**

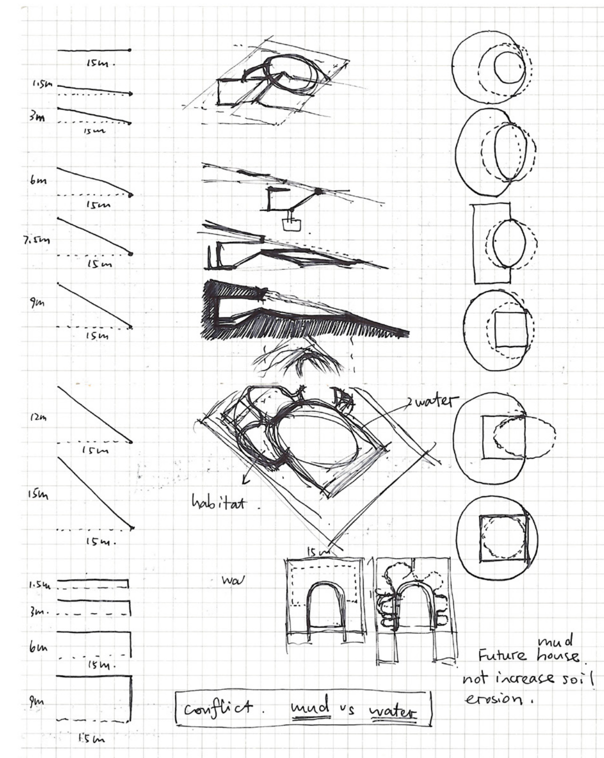


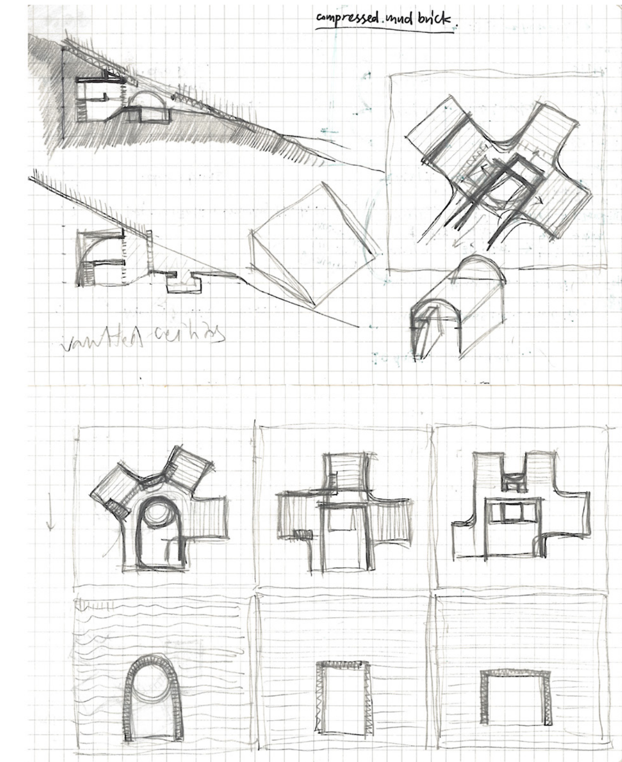


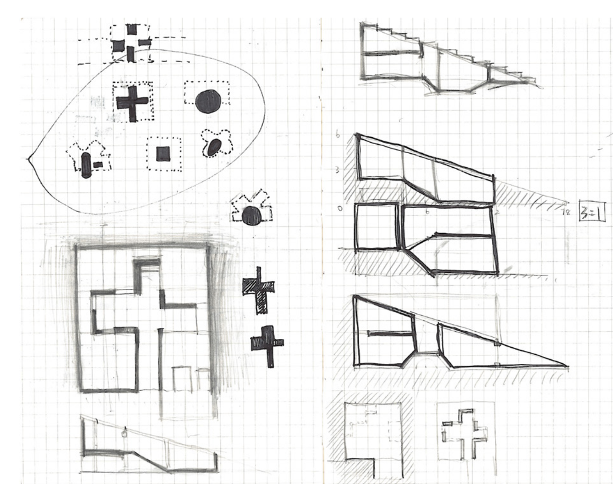


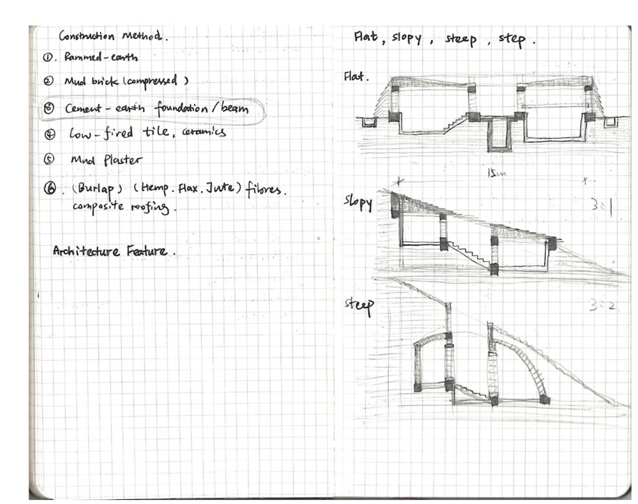


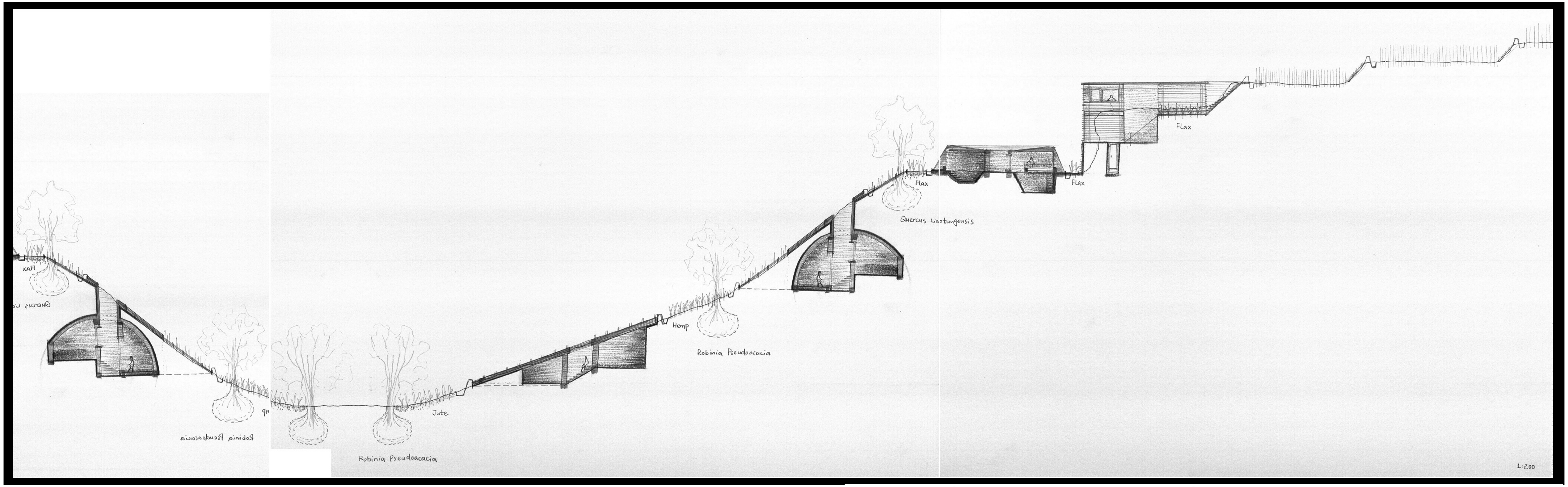




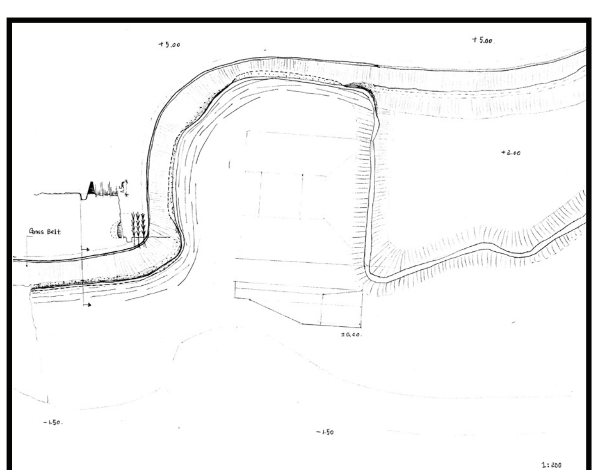




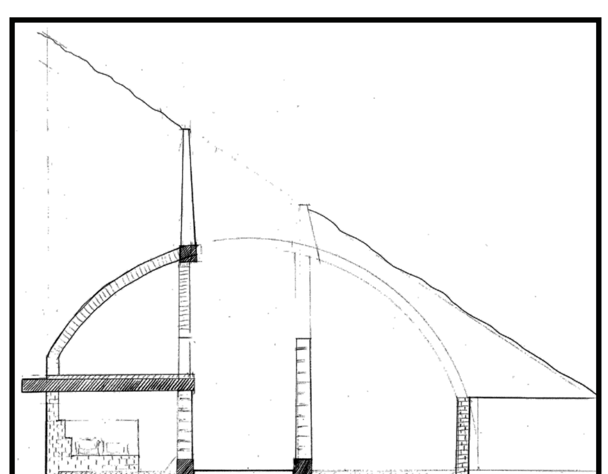




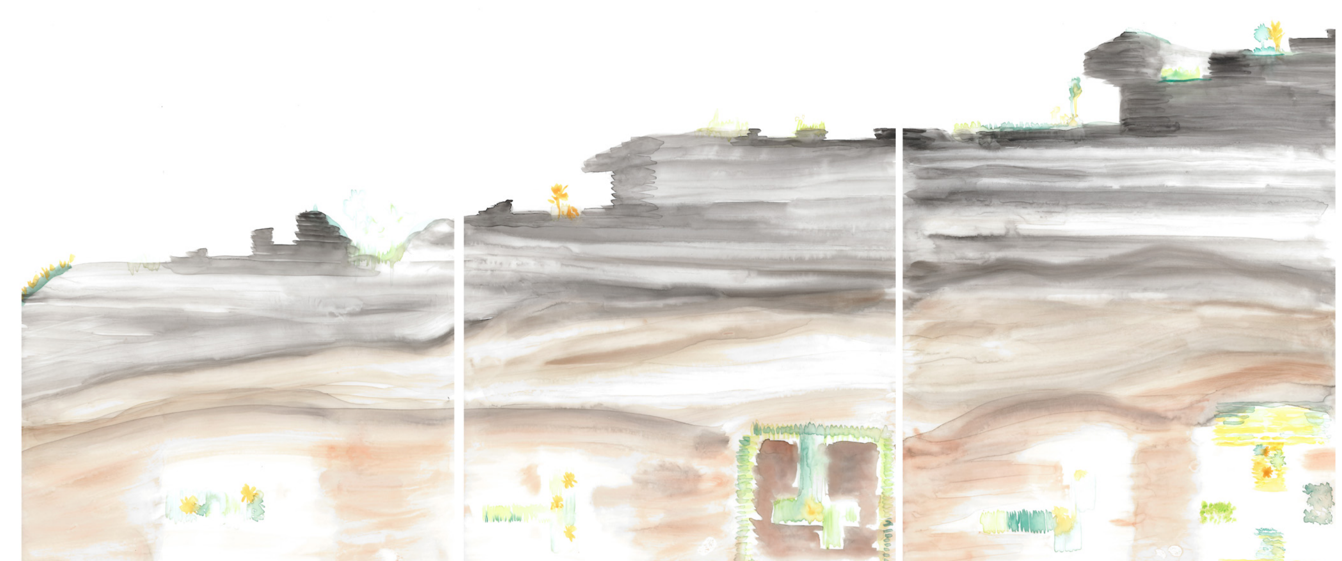
Settlement section (pencil on Bristol paper)



Settlement landscape sketch (pencil on Bristol paper)

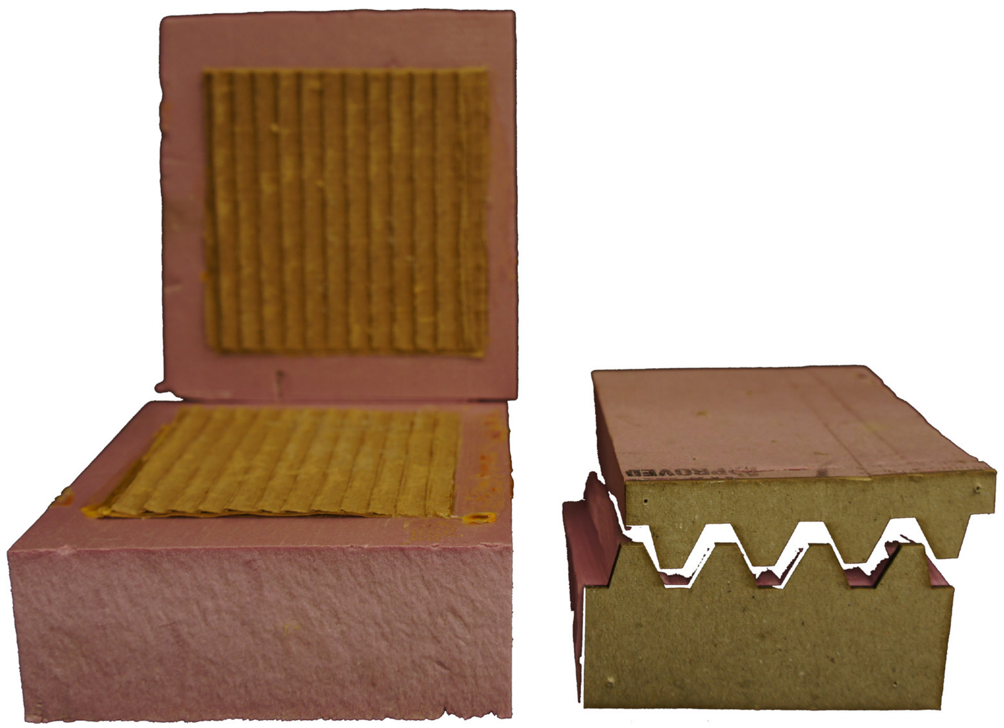


Construction sketch (pencil on Bristol paper)

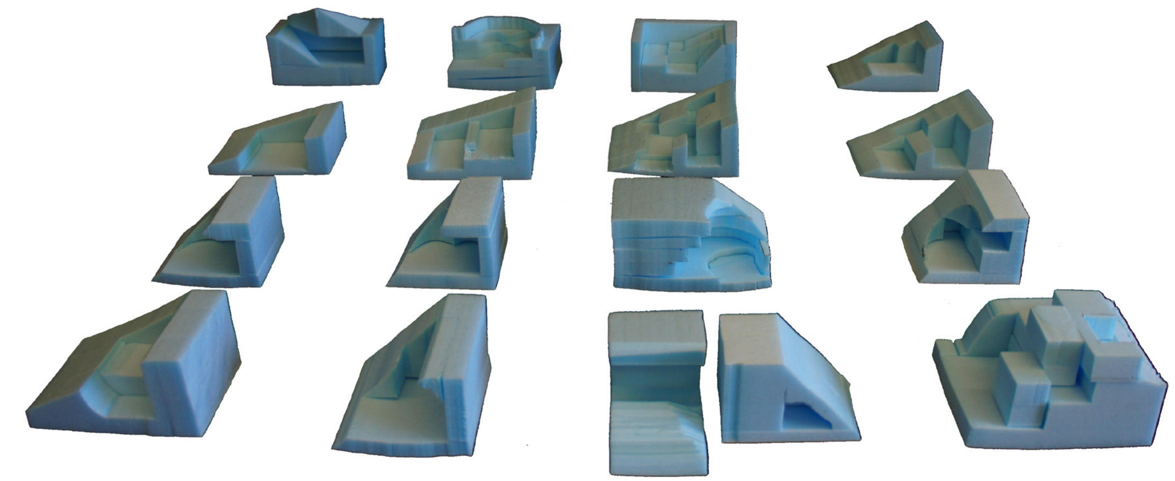


Settlement section (watercolor on paper)

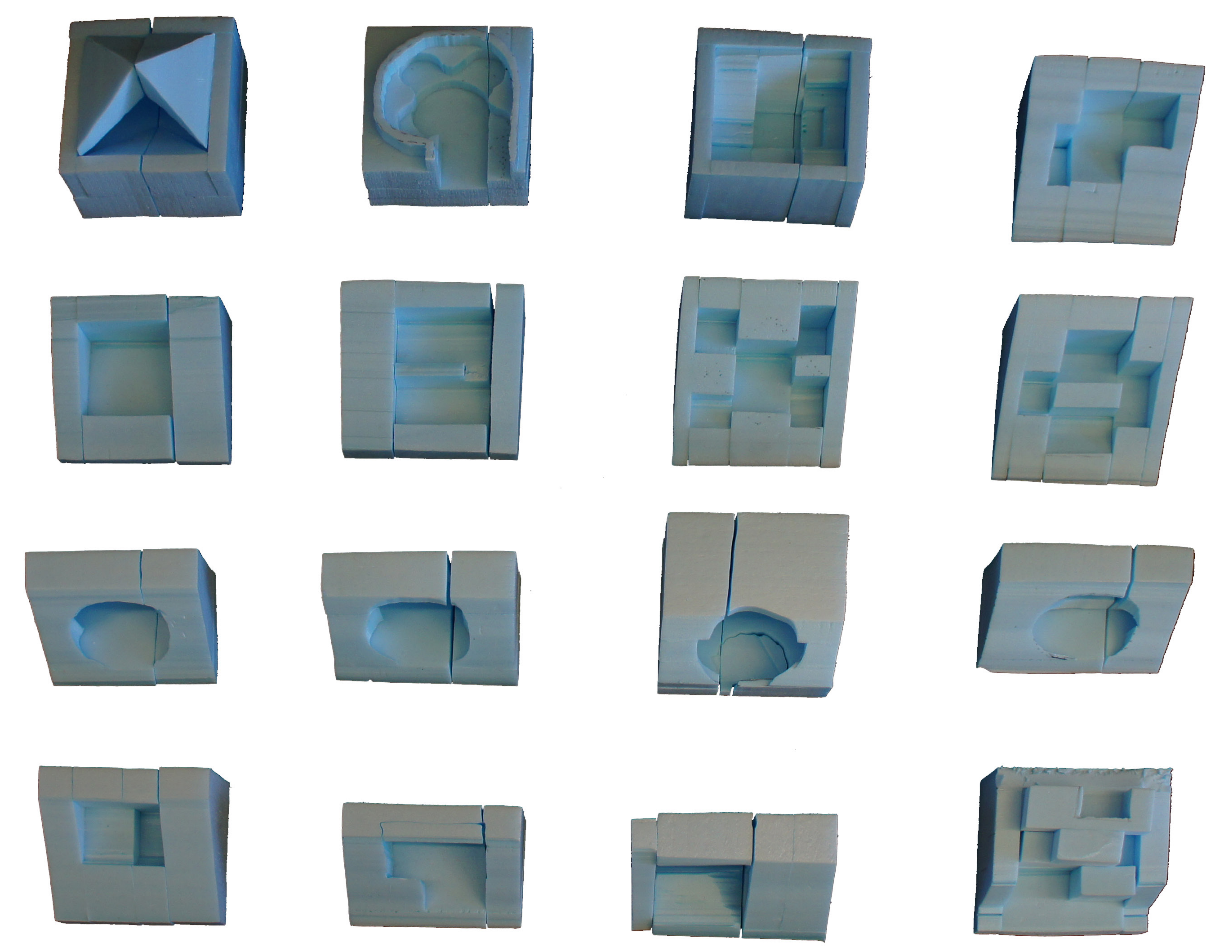
Appendix II **Working Models**

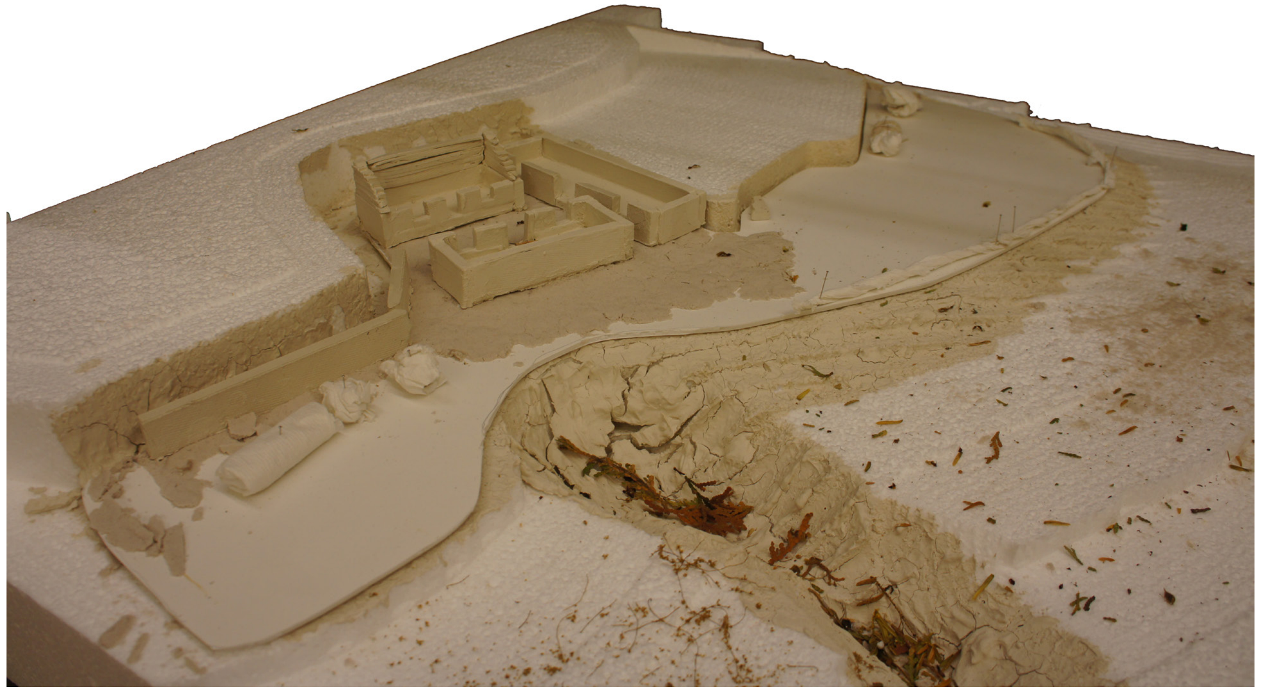


Natural Fiber Composites Testing (Burlap and wood glue on foam molds)

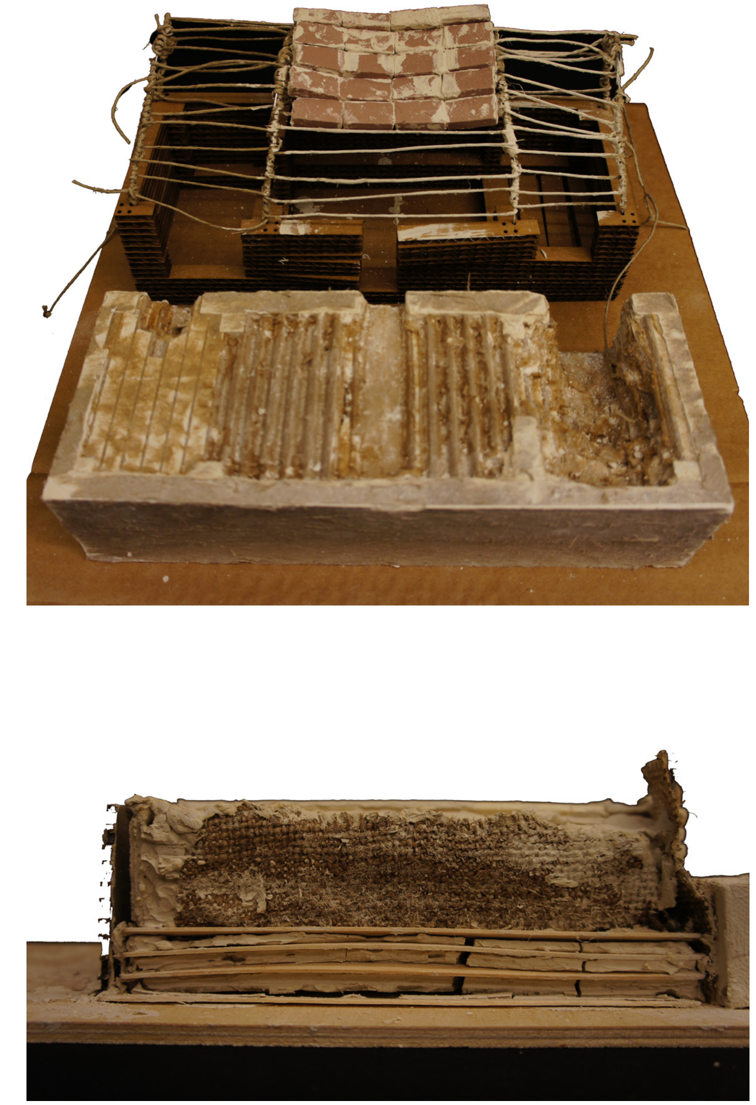


Land and Built massing models (Blue foam)

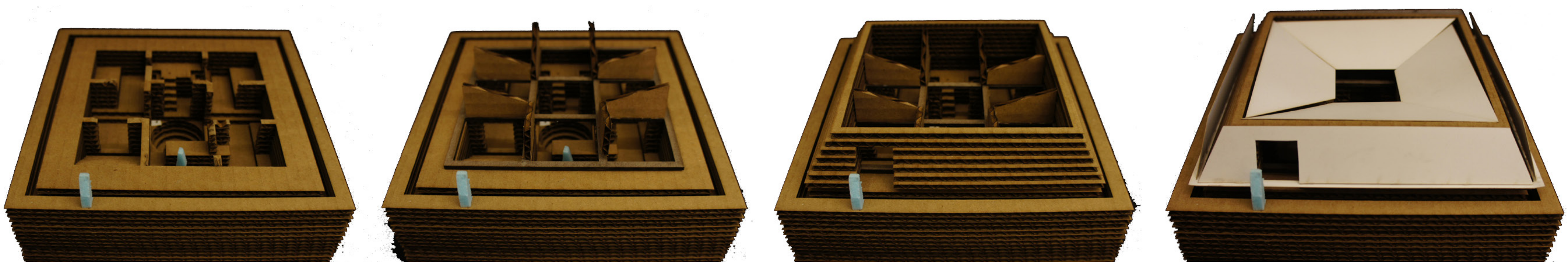




Existing household model (whilte clay on CNC white foam)



Surface rendering test (white clay, burlap and wood stick)



Working model of the Flat Type A (corrugated cardboard)

Bibliography

Methodology –

- Kenneth Frampton, "Studies in tectonic Culture: The Poetics of Construction in Nineteenth and Twentieth Century Architecture", Graham Foundation for Advanced Studies in the Fine Arts, 1995
- Andrea Deplazes, "Constructing Architecture: Material Processes Structure, A Handbook", Springer, 2005
- Alice Foxley, Vogt Landschaft, "Distance and Engagement: Walking, Thinking and Making Landscapes ", Lars Muller Publisher, 2010
- Thomas H. Jordan, "Understanding Earth" (systematic introductory to Geology and Geological methods), 1993
- "Flora Danica" http://dia-prod-mas-01.kb.dk/FloraDanica/Site/index.jsp, The Royal Library – National Library o Demark and Copenhagen University Library

Representation –

- Eduard Imhof, "Cartographic Relief Presentation", ESRI, Inc., 2007
- Günther Vogt, Vogt Landschaft, "Miniature and Panorama", Lars Muller Publisher, 2012

Earth Environment –

- A. Tsunekawa, G. Liu, N. Yamanaka, S. Du, "Restoration and Development of the Degaraded Loess Plateau, China", Springer, Japan, 2014

Earthen Construction –

- Otto Kapfinger, Axel simon, "Haus Rauch", Birkhauser, Basel, 2010
- Paul Jaquin and Charles Augarde, "Earth Building: History, science and conservation", Building Research Establishment, UK, 2012
- Julian Keable & Rowland Keable "Rammed earth Structure: A Code of Practice", Practical Action Publishing, 2012
- http://www.eartharchitecture.org/, contemporary earth architecture updates

Rural Landscape/Village Planning –

- Swiss Alps village development, Gion A. Caminada, ETH Zürich
- Works of China New Rural Planning and Design Institute (includes practical work of Taiwanese architect Hsieh Ying-chun, artist Sunjun, rural issue expert Li Changping).
- Works of Wu Zhi Qiao, rural bridges across rural China landscape (includes earthen construction work of Xi'an Architecture and Technology University)

Low-cost (Econ & Environ) and Community Housing –

- Andres Lepik, "Small Scale, Big Change: New Architectures of Social Engagement", The Museum of Modern Art, New York, 2010
- Mofens Prip-Buus, "Jorn Utzon Logbook Vol.1: The Courtyard Houses", Blondal, 2004

Organization links –

http://www.earth-auroville.com/ UNESCO Chair Earthen Architecture, based in Auroville India
http://craterre.org/ CRATerre-EAG (International Centre for Earth Construction)
www.lehmtonerde.at/en/ Lehm – Ton – Erde - Loam Clay Earth, Martin Rauch, Vorarlberg

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